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Pressure dependence of the magnetic properties of MnRhX (X = P, As)

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Abstract

The pressure dependence of the Curie temperatures of the Fe₂P-type intermetallic compounds MnRhP, MnRhAs and MnRhAs_{0.6}P_{0.4} was investigated up to 8 GPa. For MnRhAs both the Curie temperature T_C and the temperature T_i of the transition from AF₁ to the canted state increased with pressure. However, T_i decreased abruptly at 5 GPa where a pressure-induced ferromagnetic transition was observed. In contrast, the rate of increase of T_C increased substantially at this pressure. The large positive pressure dependence of T_C in these compounds is found to be strongly related to the value of the lattice parameter c .

1. Introduction

The ternary intermetallic compounds MnRhX (X = As, P) and the quasi-ternary compounds MnRhAs_{1-x}P_x crystallize into the Fe₂P-type structure (space group: $P\bar{6}2m$) [1, 2]. These compounds are considered to be magnetically pseudo-two-dimensional. In these crystals, Mn and Rh atoms form a layer structure, consecutive Mn layers being separated by a layer of Rh + As(P) atoms along the c -axis. At atmospheric pressure, MnRhP is a simple ferromagnet with the Curie temperature $T_C = 401$ K [2], whereas MnRhAs has wide variety of interesting magnetic phases depending upon temperature. The volume of MnRhAs is larger than that of MnRhP. Therefore, MnRhAs was expected to become a simple ferromagnet under high pressure. In addition, it was suggested that the chemical and external pressure might be equivalent in MnRhAs_{1-x}P_x [3]. The purposes of the present experiments are as follows:

- (1) the search for a new pressure-induced magnetic phase transition in MnRhAs;
- (2) an investigation of the effect of pressure on T_C for MnRhAs_{1-x}P_x at high pressures up to 10 GPa.

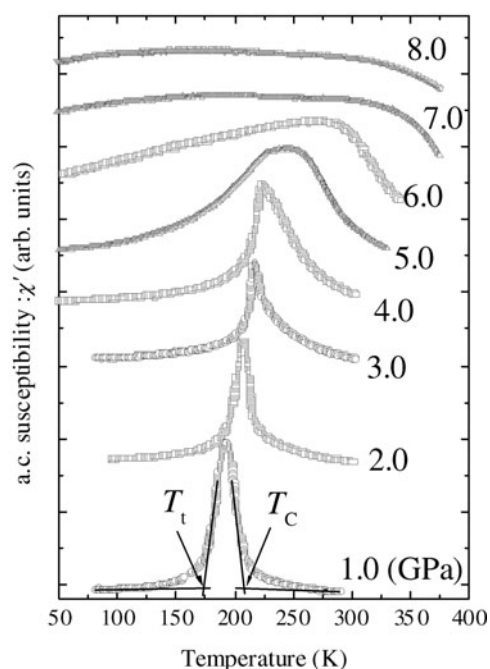


Figure 1. Temperature dependences of the real part of the AC susceptibility under various pressures in MnRhAs.

2. Experiment

Polycrystalline samples of MnRhX ($X = \text{As}, \text{P}$) were prepared using a ceramic method. The crystal structures were investigated by using the x-ray diffraction technique to ensure that we had single phases of the Fe_2P type. All the samples used in this work were confirmed to be single phase.

A cubic anvil apparatus was used in the AC susceptibility measurements under high pressure [4, 5].

Powder samples were pressed into cylinders with radius 0.7 mm and length 1.5 mm. To detect the signal of the AC susceptibility, a primary and a secondary coil of Cu wire coated with polymer insulator, 40 μm in diameter, were wound around the sample. The sample and the coil system were inserted with the pressure medium in a Teflon capsule. This capsule was set in the centre of a cubic cell made of pyrophyllite of 6 mm edge length. The AC magnetic field was generated in the primary coil and the signal of the AC susceptibility induced in the secondary coil was detected using a lock-in amplifier.

3. Results and discussion

The observed temperature dependences of the AC susceptibility in MnRhAs under various pressures up to 8 GPa are shown in figure 1 and on expanded scales in figure 2. The temperature of the magnetic phase transition from the low-temperature antiferromagnetic phase to the canted state, T_t , and that for the transition from the canted state to the high-temperature AF_{II} state, T_C , were determined as shown in figure 1. Both T_t and T_C increased gradually with increasing pressure up to 4 GPa, at which point T_t decreased abruptly, vanishing just above 5 GPa. On the other hand, T_C continued to increase at a greater rate. Thus, there is a boundary point at around 4.0 GPa at which the pressure derivative dT_C/dp changed abruptly and above

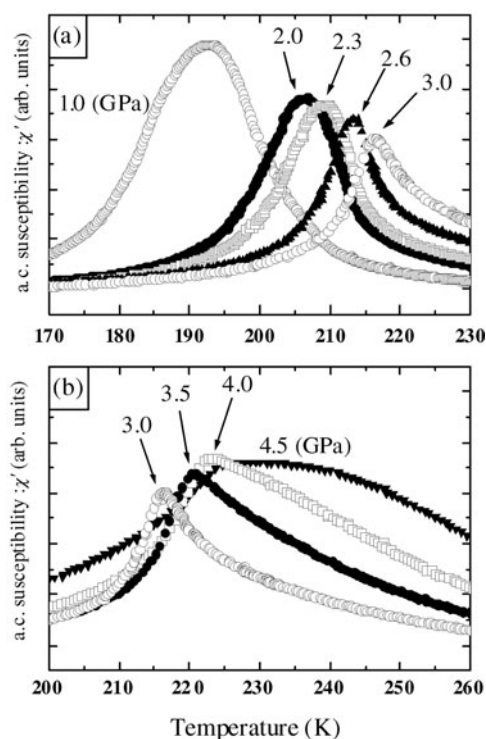


Figure 2. Susceptibility versus T curves on expanded scales under various pressures for MnRhAs.

which the shape of the AC susceptibility versus temperature curve became ferromagnetic-like. The value of dT_C/dp for the lower-pressure range up to 4 GPa is 7.7 K GPa^{-1} , which is in good agreement with that obtained by Kanomata *et al* up to 1.5 GPa [2]. In the higher-pressure range above 4 GPa, $dT_C/dp = 30.0 \text{ K GPa}^{-1}$, which is very large compared with all other data previously reported [6] for Fe_2P -type compounds. Judging from this fact and considering the shape of the $\chi'-T$ curves above 5.0 GPa in figure 1, it can be concluded that a phase transformation from the complex magnetic state to a simple ferromagnetic one takes place. If T_p coalesces with T_C at around 4–5 GPa, it should be considered that there are two kinds of T_C , below and above this pressure. In the lower-pressure region, T_C is defined as the temperature of transition from the canted state to the antiferromagnetic one, and in the higher-pressure region, T_C is the usual Curie temperature for the transition from the ferromagnetic state to the paramagnetic one. The P - T phase diagram determined from the present experiment is shown in figure 3.

A pressure-induced magnetic phase transition was observed in MnRhAs at 5 GPa [7], as shown in figure 3. At this pressure, the pressure derivative of T_C increased suddenly from 7.7 to 30 K GPa^{-1} , although this transition was not accompanied by any structural transition. The pressure derivative of T_C for $\text{MnRhAs}_{0.6}\text{P}_{0.4}$ was measured and the rate of increase $dT_C/dp = 31 \text{ K GPa}^{-1}$ was found to be almost the same as that for MnRhAs above 5 GPa. dT_C/dp for MnRhP was also obtained up to 10 GPa, and the value was 14.3 K GPa^{-1} [8].

To make clear the magnetic properties in this system, observed Curie temperatures of MnRhP, MnRhAs and $\text{MnRhAs}_{0.6}\text{P}_{0.4}$ were plotted in figure 4 as a function of the c -value. In this figure it is seen that all of the experimental points concentrate close to a single temperature versus c curve. The large positive values of dT_C/dp observed in the ferromagnetic phase for the three compounds were found to be strongly related to the value of the lattice parameter c .

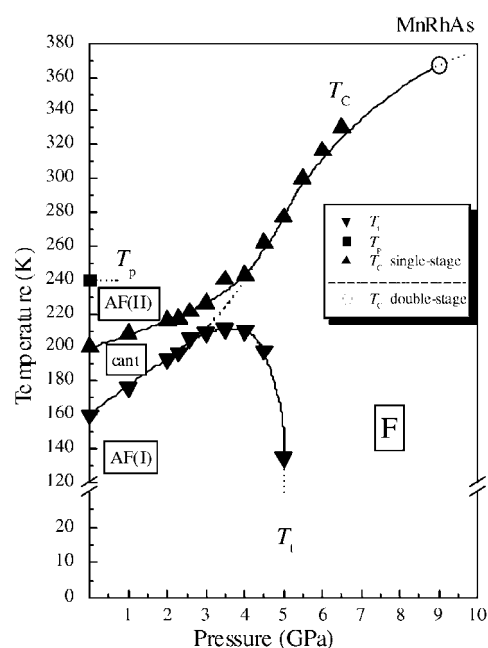


Figure 3. The P - T magnetic phase diagram of MnRhAs.

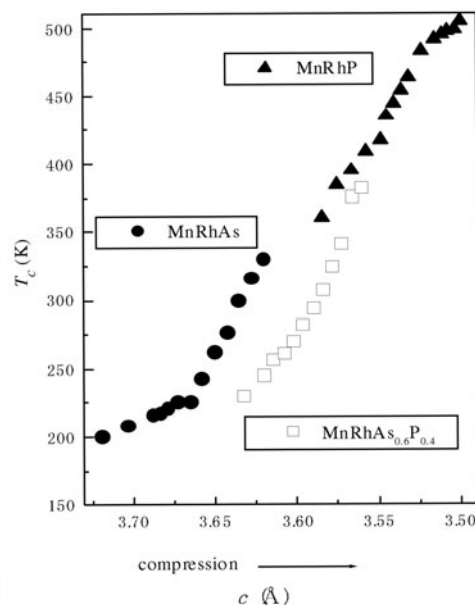


Figure 4. Observed Curie temperatures of MnRhP, MnRhAs and MnRhAs_{0.6}P_{0.4} plotted against the lattice parameter c .

The most plausible mechanism for the ferromagnetic exchange is the Ruderman–Kittel–Kasuya–Yosida (RKKY) interaction between Mn–Mn atoms along the c -axis through a layer of Rh + As(P) atoms [9].

4. Conclusions

A pressure-induced ferromagnetic transition from a canted state was found in Fe₂P-type MnRhAs around 5 GPa. Above this pressure the Curie temperature increased at the large rate of 30 K GPa⁻¹. This large rate of increase is common to the ferromagnetic phases of MnRhP, MnRhAs and MnRhAs_{0.6}P_{0.4}, and is explained by considering the RKKY interaction between Mn–Mn atoms along the c -axis.

References

- [1] Chenevier B, Bacmann M, Fruchart D, Senateur J P and Fruchart R 1985 *Phys. Status Solidi a* **90** 331
- [2] Kanomata T, Shirakawa K, Yasui H and Kaneko T 1987 *J. Magn. Magn. Mater.* **68** 286
- [3] Zach R and Naukowe Z 1997 *Politech. Krakow.* **21** (in English)
- [4] Mori N, Takahashi H and Miyane Y 1990 *Solid State Phys. (Agune (Co. Ltd.): Tokyo)* **25** 185
- [5] Endo S, Sawada T, Tsukawake T, Kobayashi Y, Ishizuka M, Deguchi K and Tokunaga M 1999 *Solid State Commun.* **112** 655
- [6] Kanomata T, Kawashima T, Yoshida H and Kaneko T 1994 *AIP Conf. Proc.* **309** 1469
- [7] Fujii N, Zach R, Ishizuka M, Ono F, Kanomata T and Endo S 2001 *J. Magn. Magn. Mater.* **224** 12
- [8] Nishino M, Fujii N, Endo S, Kanomata T and Ono F 2000 *Phys. Lett. A* **276** 133
- [9] Ono F, Inoue H, Wei S, Takahashi A, Endo S, Fujii N, Kanomata T, Zach R and Iwase A 2001 *J. Alloys Compounds* **317–8** 254