Vol. 34 (2003) *ACTA PHYSICA POLONICA B* No 2

DRAMATIC CHANGE OF THE MAGNETIC CHARACTERISTICS IN $YbMn_2Ge_2$ UNDER HIGH PRESSURES*

T. Fujiwara, H. Fujii

Faculty of Arts and Sciences, Hiroshima University
Higashi-Hiroshima, 739-8521, Japan

Y. Uwatoko

Institute for Solid State Physics, University of Tokyo, Kashiwa 277-8581, Japan

K. Koyama, M. Motokawa

Institute for Material Research, Tohoku University, Sendai 980-8577, Japan

and T. Shigeoka

Faculty of Science, Yamaguchi University, Yamaguchi 753-8512, Japan

(Received July 10, 2002)

Pressure effect on magnetic properties of $YbMn_2Ge_2$ was investigated by magnetization measurements under hydrostatic pressures up to 2.0 GPa in temperature range from 2 to 400 K using single crystalline sample. The results indicated that the antiferromagnetism in $YbMn_2Ge_2$ unusually and strongly depends on pressure. The anomalous pressure dependence may mainly be originated in the fact that Yb ion is in a mixed valence state between Yb^{2+} and Yb^{3+}.

PACS numbers: 75.50.Ee, 74.62.Fj, 74.25.Ha, 75.30.Kz

1. Introduction

During the last decade, much attention has been paid to the magnetic characteristics of intermetallic compounds RMn_2Ge_2 [1]. This system crystallizes in $ThCr_2Si_2$ type body centered tetragonal structure in which the Mn

* Presented at the International Conference on Strongly Correlated Electron Systems, (SCES 02), Cracow, Poland, July 10–13, 2002.

atoms construct a simple tetragonal framework with strong two-dimensionality. Among the RMn_2Ge_2 family, the physical properties of $YbMn_2Ge_2$ have not been clarified in details except a few works by X-ray analysis [2], Mössbauer spectroscopy [3] and powder neutron diffraction [4] because of a difficulty of producing single phase sample. Fortunately, we recently succeeded to grow the single crystal $YbMn_2Ge_2$. From magnetization measurement of the single crystal under magnetic field up to 13 T, we clarified that this system indicated an antiferromagnetic ordering (AFM I) below $T_{N1} \sim$ 400 K and transformed into another antiferromagnetic state (AFM II) at $T_{N2} = 163$ K with decreasing temperature. Furthermore, a novel magnetic behavior appeared below T_{N2} : After a metamagnetic transition field B_C from AFM II to a field induced state (Fi) showed a minimum around $T =$ 130 K, the value of B_C significantly increased just below T_{N2} with increasing temperature [5]. This suggests that at least two kinds of magnetic interactions with conflicting characters such as ferromagnetic and antiferromagnetic ones compete with each other in the antiferromagnetic ground state of this system. Such a competition of magnetic interactions has not been observed in other RMn_2Ge_2 systems in stable R^{3+} ionic state [1]. Therefore, it seems that this competition is attributed to the fact that Yb ion is in a mixed valence state between Yb^{2+} and Yb^{3+} [2]. Thus, we expect that $YbMn_2Ge_2$ will show further novel magnetic behaviors under high pressure.

2. Experimental procedures

In this work, we generated hydrostatic pressure by a clamping-type high-pressure micro-cell and Daphne7373 was used as a pressure transmitting fluid. The magnetization was measured along the c-axis of tetragonal under various pressures up to 2.0 GPa using a SQUID magnetometer. The single crystals used in this work are the same as those used in the previous work [5].

3. Results and discussion

Figs. 1 (a) and (b) show the magnetizations along the c-axis at $B = 0.5$ T and 0.1 T as a function of temperature below and above 300 K under various pressures in $YbMn_2Ge_2$, respectively. The over all feature of $M(T)$ curve below 300 K under ambient pressure well reproduces that in our previous work [5]. A clear cusp feature appears at $T_{N2} = 163$ K in ambient pressure as seen in Fig.1 (a). With increasing pressure, T_{N2} linearly increases up to 271 K at 1.0 GPa, and shows a maximum at $\sim$ 1.25 GPa. After then, it markedly decreases down to 112 K at 2.0 GPa. It is to be noted that the susceptibilities in AFM II state are gradually enhanced above 1.25 GPa. On the other hand, in the $M(T)$ curve above 300 K under ambient pressure, which is not shown in Fig.1 (b), a small anomaly is observed at $T_{\rm N1}$ just above 400 K. In an inset of Fig.1 (b), we can see a small but sharp drop of magnetization just below 400 K at 1.0 GPa as well, indicating that $T_{\rm N1}$ decreases by applying pressure of 1.0 GPa. In addition, a hump of magnetization is observed in $M(T)$ curve above 350 K at 1.0 GPa. This hump feature is enhanced at 1.25 and 1.31 GPa. Furthermore, when pressure is increased up to 1.38 GPa, a clear cusp feature suddenly appears at $T_{\rm N1}$ = 386 K. With further increasing pressure, $T_{\rm N1}$ increases rapidly and $T_{\rm N1}$ reaches to $\sim$ 420 K at 2.0 GPa.

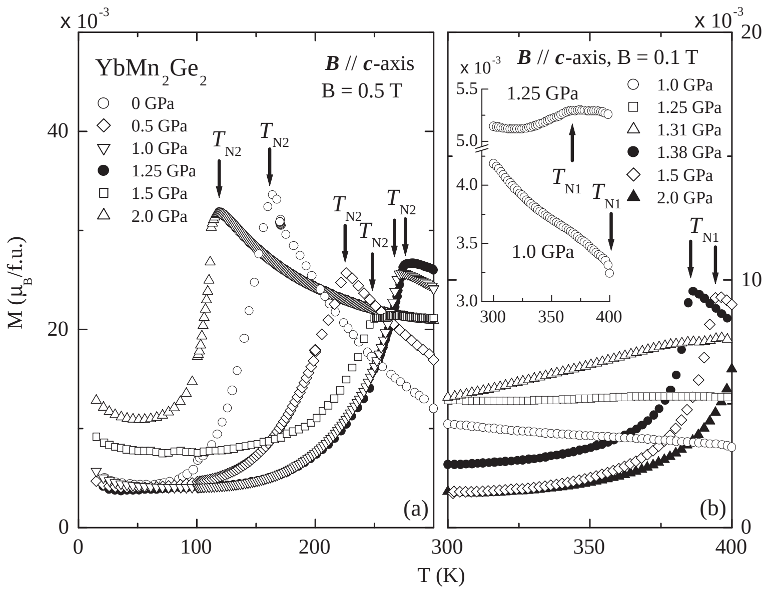

Fig. 1. (a) and (b) Magnetizations along the c-axis at B = 0.5 and 0.1 T as a function of temperature below and above 300 K, respectively, in $YbMn_2Ge_2$.

The resultant P–T phase diagram for magnetic field parallel to the c-axis in $YbMn_2Ge_2$ is given in Fig. 2. One of the notable feature is that $T_{\rm N1}$ and $T_{\rm N2}$ show a minimum and a maximum, respectively, at the same pressure region of $\sim$ 1.25 GPa. This suggests that AFM I state competes with AFM II state and a magnetic structure change occurs at $P \sim 1.25$ GPa.

We are not sure the details on why this system shows such an anomalous behavior under high pressures. However, it seems reasonable to conclude that pressure induced magnetic structural change is caused at critical pressure of $\sim$ 1.25 GPa. Because there exists significant difference between the magnetization behaviors of the system below and above $\sim$ 1.25 GPa, as is evident from Figs. 1 (a) and (b). The information about Yb valence and magnetic structure under high pressure is required to clarify the origin of

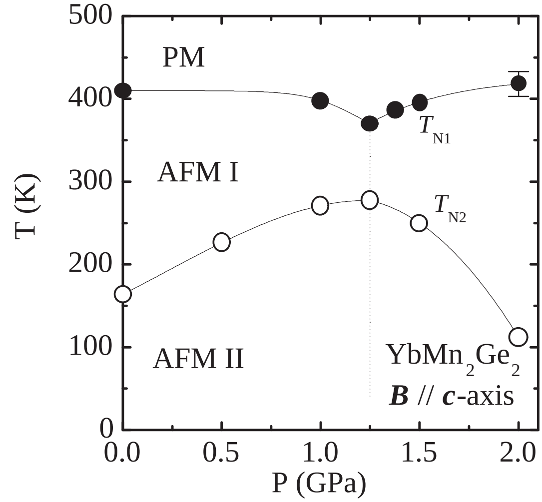

Fig. 2. P–T phase diagram of $YbMn_2Ge_2$. Where, the solid and open circles represent T_{N1} and T_{N2}, respectively, and the value of T_{N1} under $P = 2.0$ GPa was estimated from the values of T_{N1} below 1.5 GPa. Broken line represents a critical pressure at which an occurrence of magnetic structural change is expected.

the competition.

One of the authors, T. Fujiwara, would like to thank the JSPS research fellowships for Young Scientists.

REFERENCES

[1] A. Szytula, *et al.*, *Handbook on the Physics and Chemistry of Rare Earths*, Vol.12, Elsevier, Amsterdam 1989, p.133.

[2] D. Rossi, *et al.*, *J. Less-Common Met.* **59**, 79 (1978).

[3] I. Nowik, *et al.*, *J. Magn. Magn. Mater.* **185**, 91 (1998).

[4] M. Hofmann, *et al.*, *J. Alloys and Comp.* **311**, 137 (2000).

[5] T. Fujiwara, *et al.*, *Physica B* **312-313**, 864 (2002).