Magneto-volume effect in the ground and field induced states of Ce_2Fe_{17}

Yoshikazu Makihara [a,1], Hironobu Fujii [b], Tetsuya Fujiwara [b], Kazuo Watanabe [c], Kohki Takahashi [c], Keiichi Koyama [c], Mitsuhiro Motokawa [c]

[a] *Physics Department, Kyushu Kyoritsu University, Kitakyushu 807-8585, Japan*
[b] *Faculty of Integrated Arts and Sciences, Hiroshima University, Higashi-Hiroshima 739-8521, Japan*
[c] *Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan*

Abstract

@X-ray diffraction measurements on Ce_2Fe_{17} have been performed in the temperature range from 8 to 300K at the magnetic fields up to 5T. The thermal expansion curves along the principal axes for antiferromagnet and ferromagnet Ce_2Fe_{17} are presented. A distinct lattice expansion was observed simultaneously with the metamagnetic transition. This suggests that the hybridization between Fe 3d- and Ce 4f-electrons in Ce_2Fe_{17} is suppressed by the application of magnetic field.

Key words: Ce_2Fe_{17};magneto-volume effect;X-ray diffraction

The magnetism of Ce_2Fe_{17} is sensitive to alloying, magnetic field and hydrostatic pressure. Two types of magnetic structures in the ground state for Ce_2Fe_{17} have been proposed. One is a fan structure with the ferromagnetic component parallel to the basal plane and the other is a helical spin structure with no spontaneous magnetizationm1-3n.

It has been known that R_2Fe_{17} (R=rare earth) show a large spontaneous magnetostriction similar to that of Invarm4n. The thermal expansion measurements on Ce_2Fe_{17} which exhibited the fan structure in the ground state were performed by several researchers m5,6n. In this work, we have measured the temperature and magnetic field dependence of the lattice parameter for two compounds of Ce_2Fe_{17}, which exhibit the fan and the helical spin structure, respectively, and investigated the magneto-volume effect in the ferromagnetic and antiferromagnetic state.

The single-phase polycrystalline sample with a rhombohedral Th_2Zn_{17}-type structure was prepared by arc melting with subsequent annealing at 1310K for a week. The sample had no spontaneous magnetization at 5K and showed a metamagnetic transition around H=1T, indicating the helical spin structure in the ground state. Hereafter, we call this sample "antiferromagnet Ce_2Fe_{17} (Ce_2Fe_{17}(AF))". We also prepared a reference sample of Ce_2Fe_{17} with a ferromagnetic component at 5K. This sample is called "ferromagnet Ce_2Fe_{17} (Ce_2Fe_{17}(F))".

Powder X-ray diffraction measurements were carried out in the temperature range from 8 to 300K at the magnetic fields up to 5T using Fe-Kα or Cu-Kα radiationm7n. We measured (300), (024), (600) and (309) reflections, which were indexed in a hexagonal cell, to calculate the lattice parameter.

The temperature dependences of lattice parameters a and c, and the cell volume v ($=\sqrt{3}\,a^2c/2$) for Ce_2Fe_{17}(AF) and Ce_2Fe_{17}(F) are shown in Fig.1. The values of a, c and v at 0T and 300K for Ce_2Fe_{17}(AF) are 8.488Å, 12.411Åand 774.4Å^3 , which are smaller about 0.07, 0.12 and 0.25 % than those of Ce_2Fe_{17}(F), respectively. A clear spontaneous magnetostriction originated in the magnetic order of itinerant Fe sub-

[1] Corresponding author: fax:+81-93-693-3202. E-mail: makihara@kyukyo-u.ac.jp

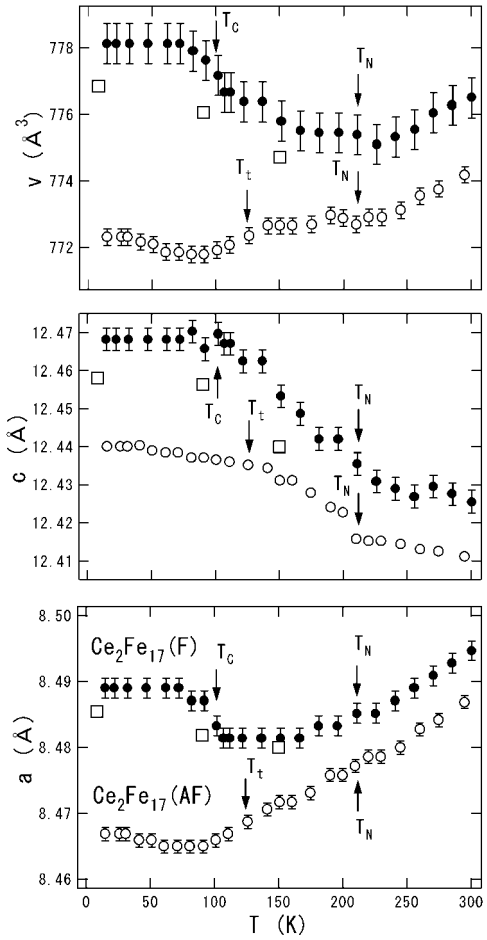

Fig. 1. The temperature dependences of the lattice parameter for Ce_2Fe_{17}. The symbols of open and closed circles represent the data for antiferromagnet Ce_2Fe_{17} (Ce_2Fe_{17}(AF)) and ferromagnet Ce_2Fe_{17} (Ce_2Fe_{17}(F)) at magnetic field of 0T, respectively. The open squares represent the data for Ce_2Fe_{17}(AF) at magnetic field of 5T.

lattice moments is observed in the c-axis below the Néel temperature T_N210K in both Ce_2Fe_{17}(AF) and Ce_2Fe_{17}(F). While, there is no distinct anomaly in the a-axis at T_N in each compound, indicating the existence of anisotropic exchange interactions. On the other hand, the thermal expansion curve of the a-axis for Ce_2Fe_{17}(AF) shows no remarkable anomaly at T_t=125K, where the helical spin structure changes to another one with a smaller wave vectorm3n. A slight upturn is observable below 100K in the curve. This result is quite different from that of Ce_2Fe_{17}(F) which shows a distinct expansion in the a-axis at T_C=100K as shown in Fig.1. Andreev et al. reported a similar anomaly at T_C=100K for Ce_2Fe_{17} which showed ferromagnetic property in the ground statem6n. As a result, the temperature dependence of v obtained for Ce_2Fe_{17}(AF) is quite different from that for Ce_2Fe_{17}(F) as shown in Fig.1. These results indicate that the helical spin structure is stabilized in Ce_2Fe_{17} with no distinct spontaneous magnetostriction in the a-axis at low temperatures. We consider that the helical structure in the ground state of Ce_2Fe_{17} is intrinsic, and the structure is easily suppressed by a slight increase of the Ce-Fe interatomic distance in the basal planem3n.

On the other hand, we observed that the Bragg peaks for Ce_2Fe_{17}(AF) shifted toward low 2θ angle side at the magnetic fields above 1T. The values of a, c and v at 5T at 8K, 90K and 150K are illustrated with open squares in Fig.1. It is noteworthy that the lattice parameters and the unit cell volume at 5T are close to those of Ce_2Fe_{17}(F) at 0T. This simply suggests that the forced ferromagnetic state in Ce_2Fe_{17}(AF) at 5T is similar to the magnetic state in Ce_2Fe_{17}(F) at 0T.

In conclusion, it has been made clear that the helical spin structure with a smaller spontaneous volume magnetostriction below T_t is stabilized in Ce_2Fe_{17}. The antiferromagnetic interaction between the iron atoms in Ce_2Fe_{17} should be influenced by the hybridization of Fe 3d-electrons with the itinerant Ce 4f-electronsm3n. The anisotropic thermal expansion in Ce_2Fe_{17} is a evidence for the effect of anisotropic hybridization. We consider that the hybridization is suppressed and the field induced fan structure is stabilized with increasing the magnetic field, accompanied with a distinct volume expansion.

Acknowledgements

We are very grateful to Dr. Y. Watanabe for his kind support in X-ray diffraction measurement at Tohoku University.

References

[1] D.Givord, R.Lemaire, IEEE Trans. Magn. **MAG-10** (1974) 109.

[2] Y.Janssen, H.Fujii, T.Ekino, K.Izawa, T.Suzuki, T.Fujita, F.R. de Boer, Phys. Rev. B**56** (1991) 13716.

[3] H.Fukuda, Y.Janssen, H.Fujii, T.Ekino, Y.Morii, J. Magn. Soc. Jpn. **23** (1999) 108.

[4] D.Gignoux, D.Givord, F.Givord, R.Lemaire, J. Magn. Magn. Mat. **10** (1979) 288.

[5] I.Medvedeva, Z.Arnold, A.Kuchin, J.Kamarad, J. Appl. Phys. **86** (1999) 6295.

[6] A.V.Andreev, A.Lindbaum, J. Alloys Compd. **297** (2000) 43.

[7] K.Watanabe, Y.Watanabe, S.Awaji, M.Fujiwara, N.Kobayashi, T.Hasebe, Adv. Cryo. Eng. **44** (1998) 747.