Magnetic phase diagram of Ce_2Fe_{17} under high pressures in high magnetic fields

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Abstract

The magnetization of Ce_2Fe_{17} was precisely measured under high pressures up to 1.2 GPa in magnetic fields up to 18 T. The magnetic phase diagram in the B-T plane is determined at 0, 0.3, 0.4, 0.6, 0.9 and 1.2 GPa. At 0 GPa, five magnetic phases exist and the application of high pressure produces two additional magnetic phases. The shape of the phase diagram changes drastically with increasing pressure.

Key words: Ce_2Fe_{17}; high field magnetization; pressure effect

The intermetallic compound Ce_2Fe_{17} has the rhombohedral Th_2Zn_{17}-type structure [1] and has no magnetic moment on the Ce atom. The magnetic structure strongly depends on the preparation method and several types of magnetic structures have been proposed [1,2]. Recently, a high quality single-phase sample of Ce_2Fe_{17} was prepared [3]. The magnetization measurement indicates that there are two magnetic transitions at $T_{mt} = 125$ K and $T_N = 210$ K. In the magnetic phases below T_N, no ferromagnetic component has been observed, consistent with the magnetic structures proposed by Fukuda et al. [2]; a modified helix below T_t and a simple helix between T_t and T_N. In the low T phase, a metamagnetic transition was found [3]. Koyama *et al.* measured the magnetization under high pressures in high magnetic fields [4]. They observed many magnetic phases in the B-T plane at 0.8 GPa. In the present paper, we have studied in detail the change of the magnetic phase diagram of Ce_2Fe_{17} in the B-T plane by applying pressure to clarify the mechanism of the field-induced and pressure-induced magnetic transitions.

The magnetization curves were measured in steady high magnetic fields up to $B = 18$ T at 0, 0.3, 0.4, 0.6, 0.9 and 1.2 GPa. Figure 1 shows the magnetization curves under an applied pressure $P = 1.2$ GPa at several temperatures. At ambient pressure, only one sharp metamagnetic transition is observed at $B_m = 0.9$ T below T_t [3]. This transition induces the ferromagnetic state from a modified helix structure. At 1.2 GPa, three transitions can be seen. The transition at

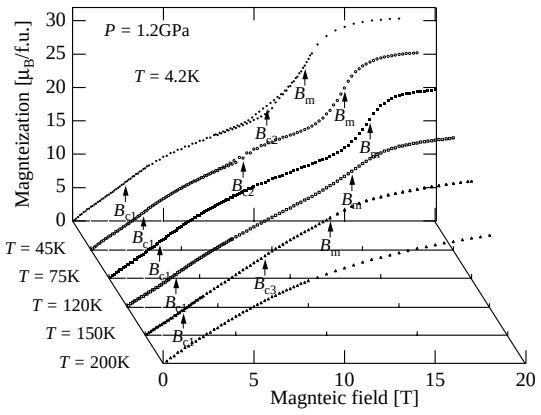

Fig. 1. Magnetization curves of Ce_2Fe_{17} up to 18 T for 1.2 GPa at various temperatures.

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B_{c1} is from a modified helical to some structure, which has a spontaneous magnetization in zero field. In the magnetic state produced at B_{c2}, the magnetization is proportional to magnetic field B, suggesting a conical structure. With increasing temperature, B_{c2} monotonically decreases and this state disappears around 75 K. By applying P of 1.2 GPa, B_m is increased to 12.8 T at 4.2 K. The magnetization nearly saturates at 18 T. With increasing B, B_m increases to 14.4 T at 75 K and then decreases. This transition is smeared out around 150 K.

Figure 2 shows the T dependence of the magnetization for 1.2 GPa at various magnetic fields. There are three peaks at T_{mt}, T_t and T_N. Considering high pressure data [4], the two magnetic states below T_{mt} and between T_t and T_N have a simple and modified helix structures, respectively. Both states continue to exist from ambient pressure. The state between T_{mt} and T_t is a pressure-induced state. T_{mt} decreases with increasing B and disappears around 12 T.

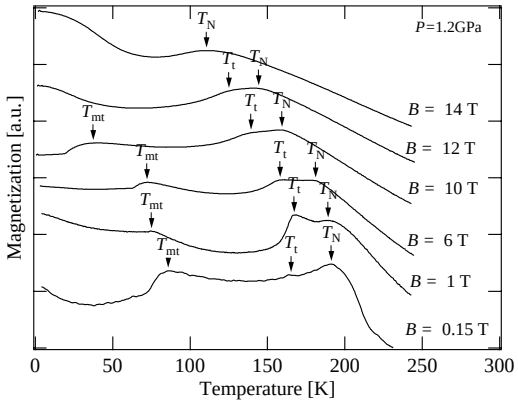

Fig. 2. Temperature dependence of the magnetization of Ce_2Fe_{17} for 1.2 GPa at various fields.

We have determined the B-T phase diagrams of Ce_2Fe_{17} at various pressures between 0 and 1.2 GPa using the data of critical temperatures and fields. As an example, we show the phase diagram for 1.2 GPa in Fig. 3. The determined diagrams are very similar to those for 0 GPa [3] and 0.8 GPa [4] reported previously, but some differences exist. In the previous phase diagram for 0.8 GPa, the phase boundary denoted by B_{c1} is found only in the temperature region $T < T_{mt}$ (see Fig. 3). In the new diagram, this boundary is distinguished below T_N. At 0.8 GPa, the phase boundary line of B_{c2} contacts with that of B_m. Above 1.0 GPa, the two boundary lines are separated. The regions of the two phases, separated by the phase boundaries denoted by T_{mt}, B_{c2}, B_t and B_{c2}, expand with increasing P. These phases are induced by applying P above 0.6 GPa. The metamagnetic transition field B_m is enhanced extremely by pressure.

As already described, the Ce atom in Ce_2Fe_{17} has no magnetic moment, that is, the 4f electrons are itinerant. In the crystal structure, there are four nonequivalent Fe sites. The observed magnetic structures [2], modified and simple helix ones, indicate the presence of competing exchange interactions between the Fe moments. Since the Fe moments are parallel to each other in the c-plane and the value of B_m is very small, the average exchange interaction will be positive. The sign and magnitude of the interaction depend strongly on the interatomic distance and the number of nearest neighbor Fe atoms. The application of P suppresses the positive interaction and enhances the negative interaction, which makes the competition of the interactions more severe and enhances the spin fluctuation of the Fe moment. The increase of B_m by the application of P can be explained by these changes. The competing exchange interactions will play an important role in the appearance of new phases and the change of the magnetic phase diagram. The enhancement of hybridization between the 4f and 3d electron states may also be related to these phenomena.

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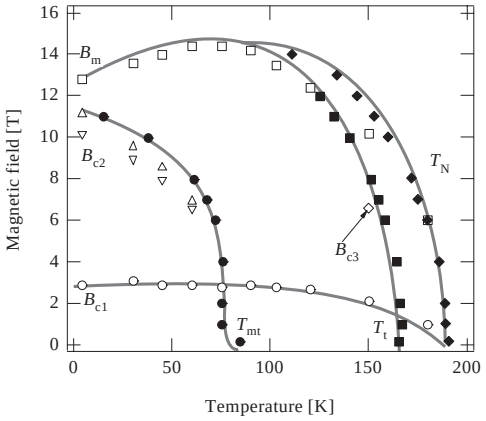

Fig. 3. Magnetic phase diagram of Ce_2Fe_{17} in the $B-T$ plane at 1.2 GPa. The open and closed symbols were determined from the measurements shown in Figs. 1 and 2, respectively.

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