M^4 scaling of negative magnetoresistance in CeSi

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Abstract

The magnetization and the magnetoresistance of the CeSi single crystal were measured at 4.2 K under the magnetic field up to 8 T. A large negative magnetoresistance attained to $-\Delta R/R(0) \approx 0.7$ was observed for the field direction parallel to the b axis. The scaling relation of $-\Delta R \propto M^4$ instead of M^2 was found. This may suggest that the correlation of the spin fluctuations exists in CeSi that has the sinusoidally modulated magnetic structure.

Key words: magnetoresistance; magnetization; scaling; CeSi

Recently, the magnetic effects on the transport properties such as a magnetoresistance (MR) effect in the magnetic materials have been extensively investigated in a fundamental interest and applications to the electronic devices.

CeSi crystallizes in the orthorhombic FeB type structure [1] and orders antiferromagnetically below $T_{\mathrm{N}} = 5.6$ K [2]. The magnetic structure has been reported to be a sinusoidally modulated structure down to 1.5 K [3]. A large anisotropy has been found by our group in the magnetization, magnetic susceptibility and resistivity measurements [4]. These facts suggest that the magnetism of CeSi can be explained as the derivative from the screw spin structures under the strong uniaxial anisotropy in the localized spin system such as the Tm metal [5]. The amplitude modulation of the localized moment leads to the existence of the dynamical transverse susceptibility, which may cause the resistivity due to the s-f interaction. In this study, we observed a large negative MR in the CeSi single crystal and found the unique relation between the MR and the magnetization M.

The samples were prepared by the Czochralski pulling method in a tri-arc furnace and checked to be a single crystal of CeSi by x-ray measurements [4]. The magnetization was measured by a vibrating sample magnetometer combined with a conventional superconducting magnet system up to 8 T. The magnetoresistance was measured by a dc 4-terminal method in the same magnet system.

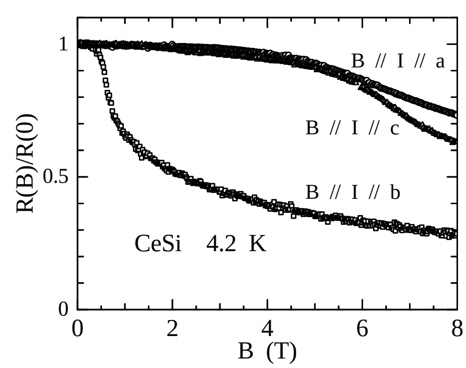

Fig. 1. Longitudinal magnetoresistance of CeSi at 4.2 K for the a, b, and c axes.

Figure 1 shows the longitudinal MR of CeSi at 4.2 K for the a, b, and c axes. The resistance R for the b axis abruptly decreases above 0.5 T and attains to 70 % reduction to the zero field value at 8 T. As for the a and c axes, the resistances slightly decrease with increasing field below 5 T and then show a rather decrease above 5 T. There are no hysteresis in the MR curves. The large

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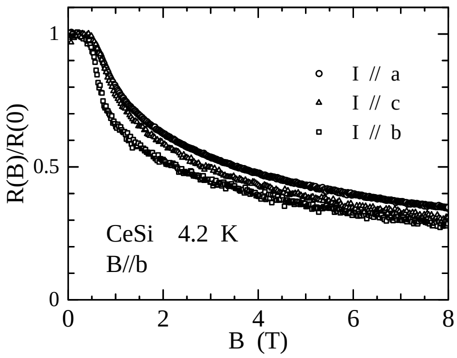

Fig. 2. Magnetoresistance of CeSi for $B \parallel b$ at 4.2 K with the different current directions for the a, b, and c axes.

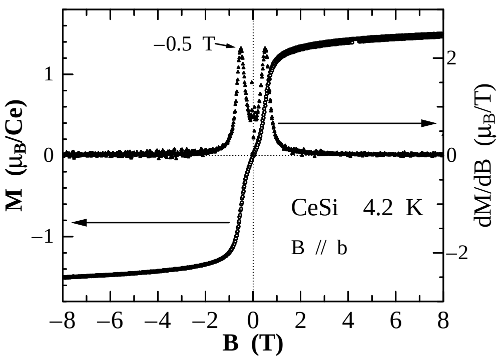

Fig. 3. Magnetization and its differential susceptibility of CeSi for the b axis at 4.2 K.

negative MR for the b axis is essentially independent of the current direction as shown in Fig. 2. This suggests that the MR due to the cyclotron motion of the carriers under the strong magnetic field as usually observed in the normal metals is less dominant in CeSi.

Figure 3 shows the magnetization and its differential susceptibility of CeSi for the b axis at 4.2 K. A clear peak in the differential susceptibility corresponding to the metamagnetic jump in the magnetization is observed at 0.5 T, which is in accord with the onset field of the MR decreasing for the b axis. Magnetic moment is 1.5 μ_B/Ce at 8 T and slightly increases.

From the data of the longitudinal MR and M for the b axis, we found the scaling relation of $-\Delta R \propto M^4$, where $\Delta R = R(B) - R(0)$, as shown in Fig.4. In the metal and alloys including the magnetic atoms, the conduction electrons are scattered by the fluctuation of the magnetic moment through the RKKY interaction, which gives the resistivity reduction proportional to the square of the magnetic moment [6]. This relation is commonly recognized in the compounds showing a large negative MR such as the GMR [7] and the

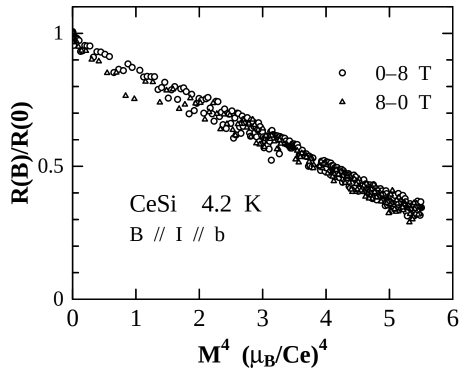

Fig. 4. Magnetoresistance $vs.$ M^4 plot.

CMR [8] compounds. In this case, however, a clear relation of $R(B)/R(0)$ to M^4 was found in all field regions. This may suggest that the correlation of the spin fluctuations exists in CeSi that has the sinusoidally modulated magnetic structure. On the other hand, the $B^{-1/3}$ dependence of the MR above 1 T was also found [9], which can be explained by the spin fluctuation theory in weekly ferromagnetic metals [10]. CeSi may be considered as the localized limit compound in the itinerant electron system.

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