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Physica B 259–261 (1999) 159–160

PHYSICA B

Magnetic properties of an anomalous phase transition around 5 K in YbSb

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Abstract

NMR measurements on ^{121}Sb have been performed to clarify the magnetic properties of an anomalous phase transition around 5 K in YbSb. The external magnetic field dependence of the NMR linewidth was measured above and below the transition temperature. The additional broadening of the NMR spectrum at the extrapolated magnetic field of 0 T in the ordered state indicates the presence of an antiferromagnetic order of an extremely reduced moment. The magnetic phase diagram of YbSb was obtained from the temperature dependence of the magnetization under various magnetic fields. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: YbSb; Reduced moment; NMR

Yb-monopnictides (YbX: X = N, P, As, Sb) attract much attention because of their unusual magnetic properties which come from the competition between the Kondo hybridization and the RKKY interactions. In these compounds YbSb has unusual phase transitions as follows. The Mössbauer spectroscopy measurements has reported the presence of two-phase transitions at 0.32 and 5 K [1]. On the other hand, neutron diffraction measurements on the same sample which was used in the Mössbauer spectroscopy did not detect any long-range magnetic ordering down to 7 mK [2]. Therefore the presence of the phase transitions has not been definitive. We had reported that NMR spectrum of YbSb shows the abrupt and distinct broadening around 5 K using the polycrystalline sample YbSb #1 prepared by ETH group [3]. In this study we have prepared a polycrystalline sample YbSb #2 which has better homogeneity than that for YbSb #1 and performed NMR measurements around 5 K using YbSb #2.

The polycrystalline sample YbSb #2 was prepared by a prereaction of the constituent elements in an evacuated and sealed quartz tube at temperatures up to 700°C, which is followed by annealing at 750°C for a week. The X-ray diffraction measurements show that the crystal structure is NaCl type and the lattice constant is 6.07 Å. The full-width at half-maximum (FWHM) of the diffraction line corresponding to the {2 2 0} plane in YbSb #2 is about a half of that in YbSb #1. This indicates that the homogeneity of sample in YbSb #2 is better than that in YbSb #1. There are small peaks which come from impurities as in YbSb #1. The relative intensity of the impurity peaks to the {2 0 0} peak in YbSb #2 is almost the same with that in YbSb #1. The NMR measurements on ^{121}Sb were performed by a phase-coherent pulsed spectrometer using the powder sample. The magnetization was measured with a SQUID magnetometer.

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PII: S0921-4526(98)00709-1

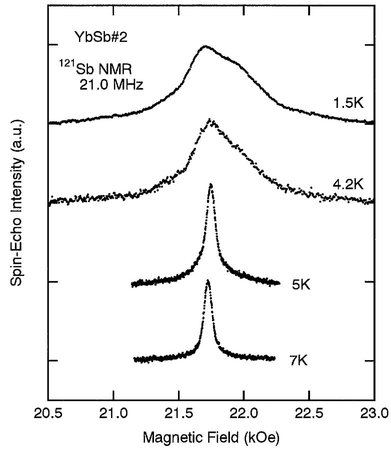

Fig. 1. Temperature dependence of the NMR spectra around 5 K in YbSb #2.

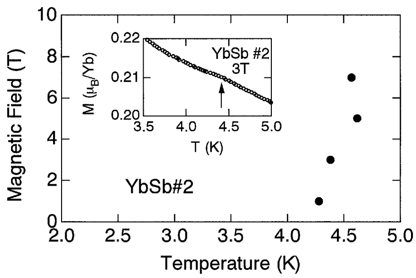

Fig. 2. Magnetic phase diagram of YbSb. Inset shows the temperature dependence of the magnetization under the external magnetic field of 3 T.

Fig. 1 shows the temperature dependence of the NMR spectra around 5 K in YbSb #2. A distinct broadening of the NMR spectrum around 5 K was observed in YbSb #2. This clearly shows the presence of the phase transition in YbSb #2 as in YbSb #1. The presence of the phase transition around 5 K in YbSb #2 is also confirmed by a small peak in the temperature dependence of the spin-lattice relaxation rate $1/T_1$. The temperature dependence of the magnetization under the magnetic field of 3 T is shown in the inset of Fig. 2. There is a small bend which was not observed clearly in YbSb #1. The similar bend was observed in each sequence under various magnetic fields. Fig. 2 shows the magnetic phase diagram obtained from these bends. The transition temperature increases with increasing the external magnetic field. This transition has also been observed in the specific heat measurements up to 10 T [4]. In order to clarify the magnetic properties of the phase transition, the external magnetic field dependence of the FWHM in the ordered and the paramagnetic states were measured.

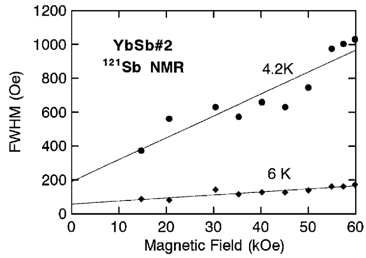

Fig. 3. External magnetic field dependence of the FWHM of NMR spectra in the ordered and the paramagnetic states. Solid lines are guide for eyes.

Fig. 3 shows the external magnetic field dependence of the FWHM in the ordered and the paramagnetic states at 4.2 and 6 K, respectively. The FWHM in the ordered state is proportional to the external field with a slope which is steeper than that in the paramagnetic state. The FWHM at the extrapolated external magnetic field of zero in the ordered state are about 130 Oe larger than that in the paramagnetic state. It seems that this additional broadening at the extrapolated field of zero comes from the ordered magnetic moment. The magnitude of the ordered moment is estimated to be about $0.07\mu_B$ from the additional broadening of 130 Oe and the calculated dipole field of $1.825\,\mathrm{kOe}/\mu_B$ assuming the type III magnetic structure. The ordering of this extremely reduced moment can explain why the transition around 5 K which is observed by the Mössbauer spectroscopy mea-surements had not been observed by the neutron diffraction experiments. Because the neutron diffraction experiments exclude the existence of only the antiferromagnetic ordering with magnetic moment larger than $0.1\mu_B$.

In conclusion, the presence of the phase transition about 5 K in YbSb was confirmed in our sample of YbSb #2 as well as in the ETH sample of YbSb #1. This phase transition in YbSb #2 was observed more clearly than that in YbSb #1 in the measurements of the magnetization and the phase diagram was obtained. The details will be published elsewhere.

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