Sb NQR study of superconducting $YbSb_2$

Y.Kohori [a,1], T.Kohara [b], N.Sato [c], T.Kinokiri [d]

[a] *Department of Physics, Faculty of Science, Chiba University, Inage-ku, Chiba 263-8522 Japan*

[b] *Division of Material Science, Graduate School of Science, Himeji Inst. of Tech. Ako-gun, Hyogo 678-1297 Japan*

[c] *Graduate School of Science, Nagoya University, Chikusa-ku, Nogoya 464-8602, Japan*

[d] *Graduated School of Science, Tohoku University, Sendai 980-8577 Japan*

Abstract

We have measured ^{121,123}Sb NQR spectra and nuclear spin- lattice relaxation rate $1/T_1$ in both normal and superconducting states of $YbSb_2$. $1/T_1$ in the superconducting state has exponential temperature dependence below the transition temperature, which indicate occurrence of an s-wave superconductivity in $YbSb_2$.

Key words: Sb NQR, superconductivity, $YbSb_2$

Many superconductors have been discovered in compounds containing Ce or U ions. On the contrary, few superconductors were observed in the systems containing Yb ions. Among them ytterbium diantimonide $YbSb_2$ having orthorhombic $ZrSi_2$ type structure becomes superconducting with a transition temperature T_C of 1.4K, which is a type- I superconductor with the critical field of 60 Oe at 0.5K [1]. In $YbSb_2$, two kinds of layers are stacked along b- axis, one consists only of Sb atoms (we hereafter refered to as Sb(1)) and the other Yb and Sb atoms (referred to Sb(II)). Then the lattice constant of the b- axis exceeds 16$\mathring{A}$, which is four times larger than those of the a- and c- axes. The electrical resistivity, magnetization, and the de Haas-van Alphen effect were measured in $YbSb_2$, which were compared with a band structure calculation [2]. The band structure suggests the Yb ions are nearly in nonmagnetic divalent state. This result is in coincidence with small and nearly temperature independent magnetic susceptibility,$\chi(T)$ = -1.4 $\times$ 10^{-4} emu/mole, and small electronic specific heat coefficient,γ = 5 mJ/moleK^2. The band structure calculation also indicates a quasi-two-dimensional feature of the Fermi surface, reflecting the anisotropic crystal structure of the system. The information of the superconducting energy gap is obtained by NMR or NQR. However type- I superconductor, in which the superconducting coherence length is larger than the magnetic field penetration depth, is not suitable for the conventional NQR measurement. Hence we have performed Sb NQR combined with a field cycling method, i.e. a small magnetic field (50 $\sim$ 60Oe) was simultaneously applied during the saturation of the Sb nuclear spin system and the detection of its NQR signal. In this way, the nuclear spin- lattice relaxation in zero magnetic field could be measured. The measurement above 1.3K were performed by ^{4}He cryostat, and ^{3}He cryostat between 0.5 and 1.3K. We observed ^{121}Sb ($I = 5/2$) and ^{123}Sb ($I = 7/2$) signals arising from two Sb sites, Sb(I) and Sb(II), as shown in Fig.1.

In the figure, ^{121,123}Sb(A) arise from one site and ^{121,123}Sb(B) arise from the other site. The assignment of the signals, A and B, to Sb(I,II) sites is difficult owing to huge magnitude of the electric field gradient and low local symmetry at the respective sites. The electric field gradient parameters of the signals are obtained as,

$^{121}\nu_Q = 64.19$MHz, $^{123}\nu_Q = 38.96$MHz and $\eta = 0.15$ for Sb(A),

$^{121}\nu_Q = 76.53$MHz, $^{123}\nu_Q = 46.46$MHz and $\eta = 0.40$ for Sb(B).

[1] Corresponding author. E-mail: kohori@physics.s.chiba-u.ac.jp

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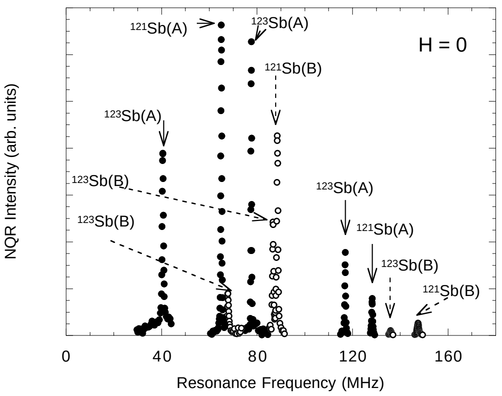

Fig. 1. ^{121,123}Sb NQR spectra in $YbSb_2$ at 4.2K, which consist of the signals from Sb(I) and Sb(II).

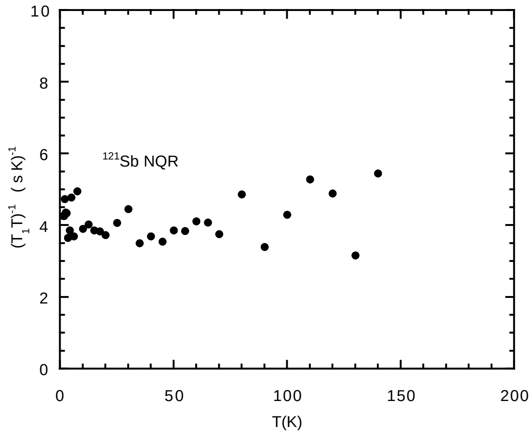

Fig. 2. T- dependence of $1/(T_1T)$ of ^{121}Sb in normal state.

Using the signal A, the temperature, T, dependence of the nuclear spin- lattice relaxation rate, $1/T_1$, was measured in normal and superconducting states. The $1/(T_1T)$ is T- independent between 2K and 150K as seen in Fig.2, which is consistent with T- independent susceptibility explained as almost no contribution from Yb ions. In this system, the ratio of $T_1(^{123}\text{Sb})/T_1(^{121}\text{Sb}) = 3.2$ is close to square of the ratio of the respective nuclear spin gyromagnetic ratios, $[\gamma\ (^{121}\text{Sb})/\gamma\ (^{123}\text{Sb})]^2 = 3.41$ and not that of the electric quadrupole moments, $[Q\ (^{121}\text{Sb})/Q\ (^{123}\text{Sb})]^2 = 0.96$, which shows $1/T_1$ is determined by only the magnetic interaction. Fig.3 shows $1/T_1$ in the superconducting state. In the superconducting state, $1/T_1$ varies exponentially at lower temperatures. The exponential T- dependence represents the existence of isotropic energy gap in $YbSb_2$. The evaluation of the energy gap from T_1 gives $2\Delta = 3.5k_BT_C$. The Sb NQR study indicates that $YbSb_2$ is an s- wave weak coupling superconductor.

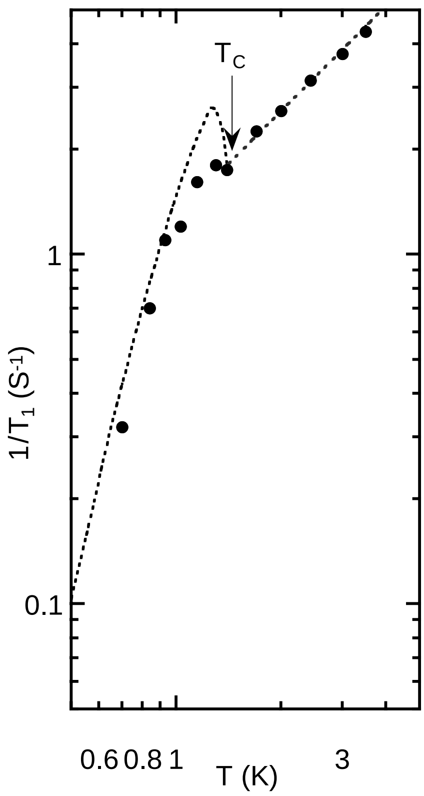

Fig. 3. T- dependence of $1/T_1$ of ^{123}Sb in superconducting state.

References

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