NMR Study on La-doped SmB_6 Single Crystals

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Introduction

A long-standing puzzle in well-known Kondo insulator(KI) SmB_6 is the ill-defined “in-gap" state[1-5]. Very recently, surface-sensitive transport experiments showed that such “in-gap" state could be ascribed to novel topological surface state(TSS)[6-8] which are consistent with recent topological Kondo insulator theory[9-11]. Surface nature instead of bulk nature became a hot issue in this field. However, previous NMR results strongly suggested that such “in-gap” state should originate from bulk not surface contribution[5,12]. Therefore, the origin of “in-gap” state should be further clarified before make better understanding on the surface nature in SmB_6. Here, we measured the spin-lattice relaxation in La-doped SmB_6 single crystals in order to study the evolution of “in-gap” state with La^{3+} doping.

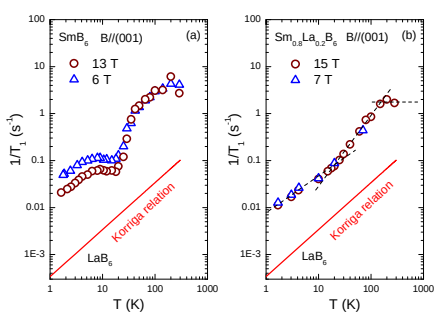
Experimental

SmB_6 and $Sm_{0.8}La_{0.2}B_6$ single crystals were synthesized by Al flux method. The details were described in Ref.13. The ^{11}B(I =3/2) NMR experiment was performed in present study. We used a home-built pulsed NMR spectrometer that employs a quadrature phase detection scheme. The measured full spectrum was similar as previous NMR results on undoped SmB_6 single crystals[12]. Measurements of the ^{11}B spin-lattice relaxation rates(T_1) were carried out from 1.7 to 300 K with magnetic field range from H = 6 to 15 T provided by a 17 T superconducting magnet at NHMFL. For the relaxation measurements, the spectrum of (-3/2, -1/2) transition was integrated and plotted as a function of variable delay after the saturation pulse. T_1 values were obtained from standard fits with the multi-exponential recovery master equation appropriate for (±3/2, ±1/2) transition.

Results and Discussion

Fig.1 Temperature dependent $1/T_1$ of SmB_6 and $Sm_{0.8}La_{0.2}B_6$ single crystals. The dash lines are guided for eyes and red solid line represents the Korringa relation in the case of LaB_6.

Our main results are shown in Fig. 1(a) and (b). The temperature dependent $1/T_1$ in undoped SmB_6 is consistent with previous result and shows a gap behavior above 20K[12]. Below 20K, a field-dependent “in-gap” state appears and shows a peak-like feature in $1/T_1$. Here, such “in-gap” state is nothing to do with surface state and should be ascribed to bulk properties. For La-doped SmB_6, above 20K, the $1/T_1$ result also shows a gap behavior which is similar as that in the undoped SmB_6 samples.



However, the gap behavior is not exponentialtype but a power-law type with index n ~ 1.5 in this case. This suggests that the bulk hybridization gap between 4f and 5d electrons could have nodes at certain region of k space. That would be very interesting to do further study on how the bulk hybridization gap collapse during La^{3+} doping. Below 20K, “in-gap” state was also observed in La-doped samples but there was no peak-like feature and field dependence in sharp contrast with the undoped case. From 1.7K to 20K, we could fit our $1/T_1$ data with power-law function with index n ~ 0.8. Usually, the $1/T_1$ of a 3D itinerant antiferromagnet follows $T^{1/2}$ at low temperature and a Fermi liquid system follows T-linear at low temperature. In our case, it could be related to a heavy fermion system for these “in-gap” states observed by our NMR technique. Further study is needed to clarify this picture.

Conclusions

A reduced gap behavior has been observed by our $1/T_1$ measurement in La-doped SmB_6 single crystals. Below 20K, a field-independent “in-gap” state appeared instead of field-dependent “in-gap” state observed by our present NMR experiment. Our result suggests that the bulk properties are beyond primary Kondo insulator scenario. This would affect the story on surface nature in SmB_6.).