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NMR/NQR studies of $LaFe_4Sb_{12}$ and $CeFe_4Sb_{12}$

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The family of filled skutterudites with the general formula RM_4X_{12} (R = rare earth, M = Fe, Ru, or Os, X = P, As, or Sb) has attracted a great deal of interest, because these compounds show a wide variety of transport and magnetic properties at low temperatures. Among them, RFe$_4$Sb$_{12}$ compounds show various ground states, e.g., $LaFe_4Sb_{12}$ is a non-superconducting metal[1], $CeFe_4Sb_{12}$ is a semimetallic heavy-fermion compound[2], and $NdFe_4Sb_{12}$, $SmFe_4Sb_{12}$ and $EuFe_4Sb_{12}$ show a ferromagnetic transition[3]. In this report, we focus on the magnetic properties of filled skutterudite antimonides $LaFe_4Sb_{12}$ and $CeFe_4Sb_{12}$ at low temperatures via the microscopic probes of ^{121,123}Sb-nuclear quadrupole resonance (NQR) and ^{139}La-NMR.

In $LaFe_4Sb_{12}$, the nuclear spin-lattice relaxation time T_1 of Sb nuclei deviates from the relation T_1T = constant above 4.2 K, where $1/T_1T$ has a Curie-Weiss temperature dependence $1/T_1T = C/(T+\theta)$ with $\theta \sim 30$ K. The temperature dependence of the Knight shift of ^{139}La nuclei, which is related to the susceptibility at $q = 0$, is scaled to that of $1/T_1T$ above 40 K. This relation strongly suggests that ferromagnetic fluctuations are predominant in $LaFe_4Sb_{12}$. We also point out that $LaFe_4Sb_{12}$ is situated close to the ferromagnetic instability due to the small Weiss temperature in the Curie-Weiss behavior of $1/T_1T$ and the Knight shift.

In $CeFe_4Sb_{12}$, $1/T_1$ shows an activated temperature dependence $1/T_1 \propto \exp(-\Delta/k_BT)$ above 50 K with an energy gap $\Delta/k_B = 200$ K. On the other hand, $1/T_1$ is proportional to the temperature below 30 K. This behavior is explained by a pseudogap model, which is suggested to be induced by the effect of the hybridization between Ce $4f$ and conduction electrons.

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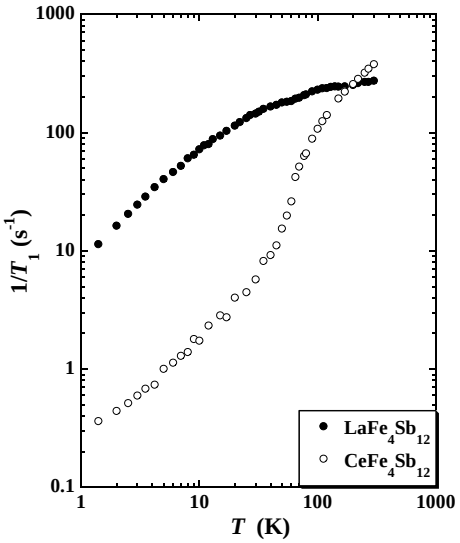

Figure 1: Temperature dependencies of the nuclear spin-lattice relaxation rates $1/T_1$ for $LaFe_4Sb_{12}$(●) and $CeFe_4Sb_{12}$(○).