(O2-1)

Ultrasonic investigation on Sm-filled skutterudites: Summary and prospect

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Sm-based skutterudites show interesting properties. We have investigated three Sm-based Skutterudits, $SmRu_4P_{12}$, $SmFe_4P_{12}$ and $SmOs_4Sb_{12}$ by ultrasonic measurements, so far. We will make a brief summary on the results of the ultrasonic investigations for these compounds, and show remaining problems and prospects.

$SmRu_4P_{12}$ shows a peculiar Metal-Insulator (M-I) transition at $T_{\rm MI} = 16.5$ K and a successive magnetic phase transition at $T_{\rm N} = 14$ K. Lattice distortion associated with the M-I transition has not been observed, so far. This fact takes exception to the common knowledge that the M-I transition accompanies a lattice distortion. In this sense, the M-I transition of $SmRu_4P_{12}$ is triggered by pure electronic origin. We have proposed an octupole ordering scenario for this system [1]. An evidence for the breakdown of Time Reversal Symmetry has been reported [2]. On the reason why the octupole ordering stable is, we have found a remarkable elastic softening has been found in $SmRu_4P_{12}$ at low temperatures below 3 K [3]. This softening is originated from either tunneling motion between multi-well potentials or a high DOS near fermi energy provides an elastic softening. Quasi-Kondo phenomena due to the Dynamical Jahn-Teller effect have been predicted theoretically for the case of Pr-based skutterudite [4].

We have pointed out that the Grüneisen parameter Ω for $T_{\rm N}$ is extremely large. Due to the large Ω value, $T_{\rm N}$ may exceed $T_{\rm MI}$ under hydrostatic pressure. We have found a large elastic softening in the transverse elastic constant in 0.5 - 0.6 GPa (P1-29). We suppose that this enhancement in the elastic softening caused by the multi-critical point between $T_{\rm MI}$ and $T_{\rm N}$. This phenomenon can be explained in the framework of the octupole scenario.

$SmFe_4P_{12}$ undergoes a ferromagnetic transition at $T_{\rm C} = 1.6$ K [5]. This compound has attracted attention due to a possible example of ferromagnetic Kondo system. $(C_{11} - C_{12})/2$ shows an anomaly around 70 K, and can be analyzed by CEF effect between Γ_5 ground state and Γ_{67} excited state with the energy separation $\Delta E = 150$ K. There are a controversy between the ultrasonic measurement and the specific heat one. The specific heat shows a broad maximum around 25 K. This corresponds to $\Delta E = 70$ K, if it comes from CEF effect.

$SmOs_4Sb_{12}$ has a heavy electron mass, and its large γ value of 0.82 J/K^2 $\cdot$ mol is insensitive agaist the magnetic field [6]. This may be a possible non-magnetic origin of the heavy fermion state in this system. There exists ultrasonic dispersion around 12 K in $(C_{11} - C_{12})/2$. However, no sign for the CEF effect was found. The relation between the rattling and the heavy electron state is highly interesting.

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