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Rattling and heavy fermion superconductivity in clathrate $\text{PrOs}_4\text{Sb}_{12}$

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We presented the elastic constants and ultrasonic attenuation measurements in clathrate $\text{PrOs}_4\text{Sb}_{12}$. The elastic softening of the $(C_{11} - C_{12})/2$ and C_{44} shows a quadrupolar fluctuation reflecting the $4f^2$ CEF state. The $(C_{11} - C_{12})/2$ in magnetic fields along $[110]$ shows a minimum around 8 T indicating the level crossing of the Γ_1 singlet and one of the $\Gamma_4^{(2)}$ triplet, which is described by one-ion quadrupolar susceptibility in fields [1]. In addition, frequency dependence (ultrasonic dispersion) around 20-30 K has been observed in the elastic constants including $(C_{11} - C_{12})/2$ with Γ_{23} symmetry in part, while in C_{44} with Γ_5 symmetry no ultrasonic dispersion was found. This thermally activated type dispersion is due to the off-center rattling of Pr ion with Γ_{23} symmetry probably characterized along $[100]$ in the cage consisting of Sb icosahedron. Around the dispersion found in the elastic constants, remarkable ultrasonic attenuation was also observed. This result reveals that the transverse ultrasound with Γ_{23} symmetry is considerably scattered by the off-center rattling which is doubly degenerated charge fluctuation state as shown in Fig. 1 [2]. At low temperatures, thermally activated rattling disappears and off-center tunneling state of Pr ion in cage may become apparent. The elastic softening of $(C_{11} - C_{12})/2$ proportional to the reciprocal temperature below 3 K down to the superconducting transition T_C may due to be the tunneling of Pr ion in the Sb icosahedron cage.

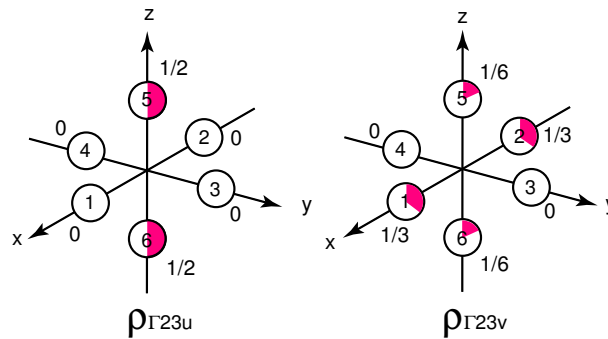


Figure 1: The Γ_{23} off-center mode along the $[100]$ direction being responsible for the rattling in $\text{PrOs}_4\text{Sb}_{12}$.

[1] T. Goto, Y. Nemoto, K. Onuki, K. Sakai, T. Yamaguchi, M. Akatsu, T. Yanagisawa, H. Sugawara, and H. Sato, J. Phys. Soc. Jpn. **74** (2005) 263.

[2] T. Goto, Y. Nemoto, K. Sakai, T. Yamaguchi, M. Akatsu, T. Yanagisawa, H. Hazama, K. Onuki, H. Sugawara, and H. Sato, Phys. Rev. B **69** (2004) 180511(R).