

Low-Energy Phonon Anomaly of $\text{CeOs}_4\text{Sb}_{12}$

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The rare-earth filled skutterudites RT_4X_{12} (R = rare earth, T = transition metal, X = pnictogen) have been studied in terms of the anomalously anharmonic lattice properties, as well as the various strongly correlated electron phenomena involving $4f$ electrons. The filled ions are located within the icosahedral X cage, and vibrate with large amplitude detected as the large Debye-Waller factors. Ultrasonic measurements of $\text{PrOs}_4\text{Sb}_{12}$ revealed dispersion of elastic constants indicative of anomalous Pr-ion motion within the Sb cage (T. Goto *et al.*: PRB **69** (2004) 180511). Recent inelastic x-ray scattering experiment of Sm-based compounds (S. Tsutsui *et al.*: Physica B **383** (2006) 142) and inelastic neutron scattering experiment of $\text{CeRu}_4\text{Sb}_{12}$ (C. H. Lee *et al.*: JPSJ **75** (2006) 123602) revealed low frequency flat phonon branches corresponding to the motion of filled atoms. We have reported the anomalous softening of phonon due to Pr vibration with decrease of temperature and the possible electron-phonon interaction in $\text{PrOs}_4\text{Sb}_{12}$ and $\text{PrRu}_4\text{Sb}_{12}$ (K. Iwasa *et al.*: Physica B **378-380** (2006) 194, J. Phys. Conference Series **92** (2007) 012122). In the present study, we have investigated the low-energy phonon spectra of $\text{CeOs}_4\text{Sb}_{12}$ using the triple-axis spectrometers TOPAN (6G) and HER (C1-1).

The figure shows phonon spectra of $\text{CeOs}_4\text{Sb}_{12}$ measured at the reciprocal lattice point $\mathbf{Q} = (0\ 3\ 3)$. It shows distinct decrease of excitation energy by 18% with decreasing temperature from 300 down to 15 K. This softening mode was confirmed to be less dispersive like an optical mode. We measured phonon spectra also at $\mathbf{Q} = (6\ -0.4\ -0.4)$, and it also exhibits softening by 10%. The energy region of this mode as well as the softening indicate that this phonon is composed of the vibration of the Ce

atoms within the icosahedral Sb cage. The presence of such anharmonic low-energy phonon in the three measured compounds suggests that it is common feature in the rare-earth filled skutterudite. We will continue the study to reveal the mechanism of the softening behavior, which may be mode coupling effect or the electron-phonon interaction involving the anomalous rare-earth vibration mode.

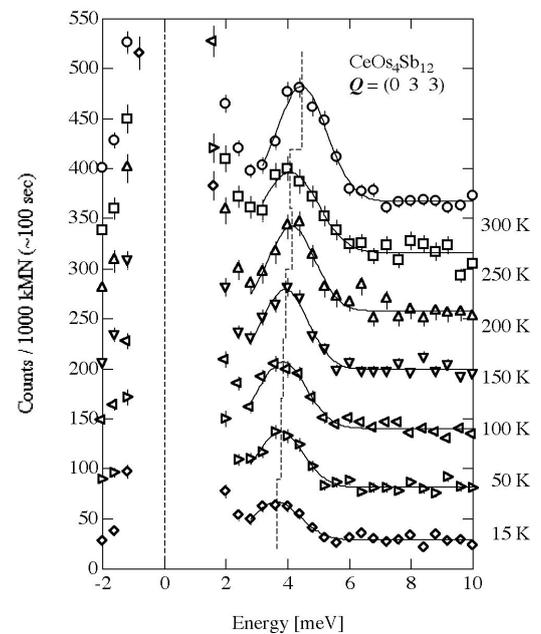


Fig. 1. Temperature dependence of the phonon spectra at $\mathbf{Q} = (0\ 3\ 3)$ of $\text{CeOs}_4\text{Sb}_{12}$.