(P2-23)

Ultrasonic measurements of quadrupole Kondo effect in $Pr_{1-x}La_xPb_3$

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$PrPb_3$ with a non-Kramars doublet Γ_3 ground in a cubic crystal causes an antiferro-quadrupole (AFQ) ordering at T_Q =400 mK [1]. The Γ_3 doublet with SU(2) symmetry has electric quadrupoles O_2^0, O_2^2 and an magnetic octupole T_{xyz}. Recently, neutron diffraction measurements have been performed on $PrPb_3$. The dates indicated the incommensurate structure of the ordered quadrupole moments, which is deduced from the field-induce antiferromagnetic moments below T_Q in low fields [2]. We have carried out ultrasonic measurements down to 20 mK under magnetic fields up to 16 T on single crystal of La diluted system $Pr_{1-x}La_xPb_3$ (x=0.02) to examine the AFQ phase diagram and the competition between inter-site quadrupole interaction and quadrupole Kondo effect. The temperature dependance of elastic constants C_{11}, C_{44} and $(C_{11}-C_{12})/2$ in $PrPb_3$ show softening with decreasing temperature below 60 K, which is described by the quadrupole susceptibility for O_2^2, and sharp kinks have been observed at T_Q. The AFQ transition temperature T_Q shifts to higher temperatures with increasing magnetic fields up to 6 T. In the case of $Pr_{0.98}La_{0.02}Pb_3$, C_{11}, C_{44} and $(C_{11}-C_{12})/2$ also exhibit softening with decreasing temperature. However, broad minimums in the elastic constants at 330 mK have been found, which corresponds to the T_Q. This result suggests that the AFQ ordering in $Pr_{0.98}La_{0.02}Pb_3$ would be considerably influenced by a screening effect of conduction electrons due to quadrupolar Kondo effect. The relations between La diluted effect and quadrupole screening effect is discussed.

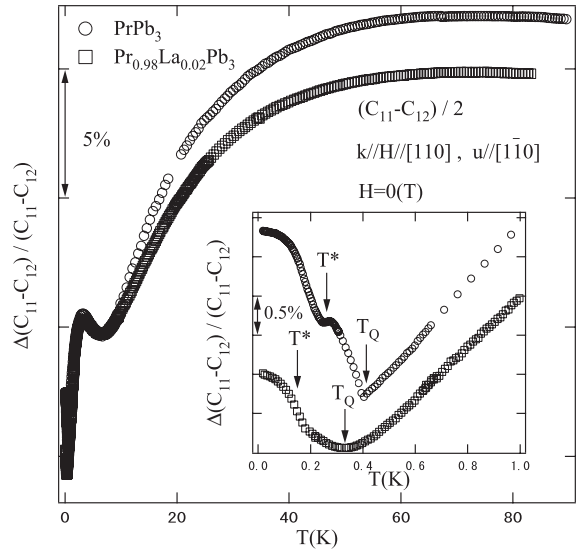

Figure 1: Temperature dependence of the elastic constants $\Delta(C_{11}-C_{12})/(C_{11}-C_{12})$ of $Pr_{1-x}La_xPb_3$ (x=0, 0.02) down to 20 mK. The inset shows anomaly corresponds to AFQ transitions and rock-in transitions in x=0, 0.02.

[1] P. Morin et al., J. Magn. Magn. Mater **30** (1982) 257
[2] T. Onimaru et al., Phys. Rev. Lett. **94** (2005) 197201