

Resonant x-ray scattering study of PrRu₄P₁₂

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Introduction

The filled skutterudite PrRu₄P₁₂ exhibits a metal-insulator (MI) transition at $T_{MI} \sim 62$ K [1] associated with a structural phase transition with a modulation vector $\mathbf{q} = [1,0,0]$ [2]. A nesting of the Fermi surface at $2\mathbf{k}_F = (1,0,0)$ suggested by a band-structure calculation induces formation of CDW which is crucial for the MI transition [3]. However LaRu₄P₁₂ does not show the MI transition although the nesting of the Fermi surface also suggested. This fact indicates that $4f$ electrons of Pr are indispensable for the MI transition. Here we report on a resonant x-ray scattering study of PrRu₄P₁₂ at Pr L_3 -edge to elucidate a modulation of electronic state of Pr. The Pr $5d$ states, which are intermediate states of resonant process, are modified by the Pr $4f$ electrons through the Coulomb interaction and/or the lattice distortion.

Experimental

Resonant x-ray scattering experiments are performed at BL-4C and 16A2 at Photon Factory. Single crystals of PrRu₄P₁₂ were grown by a tin-flux method.

Results and Discussion

Figure 1 shows the energy dependence of $\mathbf{Q} = (3,1,3)$ and $(1,3,-1)$ which are forbidden above T_{MI} . These reflections contain two components. One is non-resonant component due to the lattice distortion, whose amplitude is independent of the photon energy. The other is resonant scattering of Pr, which is enhanced near the absorption edge (~ 5.955 keV). The existence of the lattice component is evidenced by abrupt changes in intensity near the absorption edge. Observed intensity is an interference between both terms, and the interference extends to higher energy beyond the absorption edge. Because the resonant term for odd number of $h+k+l$ corresponds to the difference of anomalous scattering factor between two Pr atoms in the bcc unit cell, our results suggest a spatial ordering of two different electronic state of Pr atoms.

Figure 2 shows the temperature dependence of the intensity of a superlattice reflection measured at both resonant and non-resonant energy. The intensity at the resonant energy contains both components of lattice distortion and the anomalous scattering, while that at the non-resonant energy corresponds only to the former.

Quite similar temperature dependence at two energies indicates that the lattice distortion and ordering of electronic state of Pr occur and evolve simultaneously.

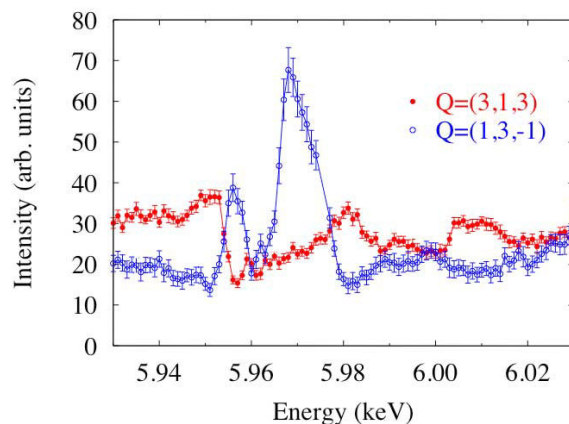


Figure 1: Energy dependence of superlattice reflections near the Pr L_3 -edge. In addition to the non-resonant component due to the lattice distortion, clear resonant feature can be seen.

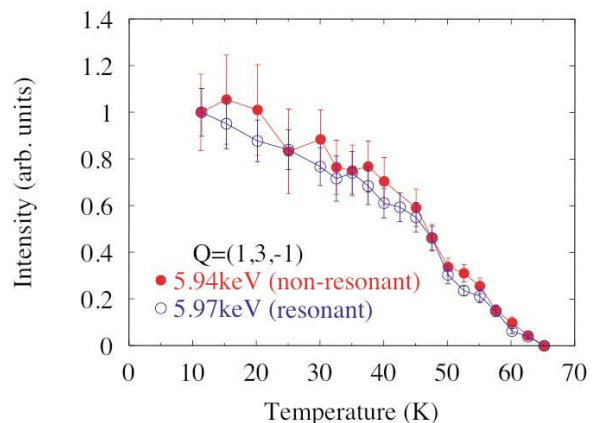


Figure 2: Temperature dependence of superlattice reflection.

References

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