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μ SR studies on filled skutterudite compounds

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Filled skutterudite compounds shows much variety of the properties. We have carried out μ SR measurements on some filled skutterudite compounds at KEK-MSL to elucidate the magnetic and the superconducting properties.

(1) Substitution effect on unconventional superconductivity in $\text{Pr}_{1-x}\text{La}_x\text{Os}_4\text{Sb}_{12}$.

The unconventional superconductivity (SC) in $\text{PrOs}_4\text{Sb}_{12}$ has been attracting much attention. One of most important feature of the unconventional SC is the breaking of the time-reversal symmetry (TRSB) which revealed by our previous μ SR measurement[1]. To confirm the role of a f-electron for the TRSB superconductivity, we performed μ SR measurement on a non-4f electron superconductor $\text{LaOs}_4\text{Sb}_{12}$. We observed temperature independent feature of zero-field relaxation rate above and below T_c . This fact indicate the absence of TRSB superconductivity in $\text{LaOs}_4\text{Sb}_{12}$ and provides convincing evidence for the 4f electrons playing an essential role for the realization of the TRSB superconductivity in $\text{PrOs}_4\text{Sb}_{12}$.

(2) Anomalous Ordered-phase in $\text{PrFe}_4\text{P}_{12}$

$\text{PrFe}_4\text{P}_{12}$ is first Pr-based heavy fermion compound and occur phase transition to ,most probably, an antiferro quadrupole (AFQ) state at $T_A=6.5\text{K}$ in zero field. We have measured zero field μ SR in $\text{PrFe}_4\text{P}_{12}$ to confirm a non-magnetic ground state and investigate the muon spin relaxation phenomena in AFQ phase. In the ZF- μ SR, we observed absence of a static magnetic field below T_A . The upper bound of the magnetic moment is estimated as $\sim 10^{-3}\mu_B$ /Pr-ion. However, slowly fluctuating field is found and relaxation rate shows the small jump at 6.5K. Possible explanation is under consideration.

(3) Nearly ferromagnetic state in $A\text{Fe}_4\text{Sb}_{12}$ ($A=\text{Sr}, \text{Ba}$)

The itinerant ferromagnetism in alkali-metal filled skutterudite $A\text{Fe}_4\text{Sb}_{12}$ ($A=\text{K}, \text{Na}$) exhibit the important role of 3d electrons in the physical property of filled skutterudite compounds. Recently, Matsuoka *et al* observed the ferromagnetic-like behavior in $A\text{Fe}_4\text{Sb}_{12}$ ($A=\text{Sr}, \text{Ba}, \text{Ca}$) from some bulk property measurements[2]. They characterized both powder and spark plasma sintered samples and found some difference of the ferromagnetic state. To clarify the ferromagnetism, we carried out μ SR measurement in spark plasma sintered $\text{BaFe}_4\text{Sb}_{12}$. We found that about 10% of the sample exhibit magnetism and other 90% still in paramagnetic phase. This feature suggest that $\text{BaFe}_4\text{Sb}_{12}$ stand nearly ferromagnetic state and ferromagnetism is induced around a few numbers of defect and/or deformation.

[1]Y.Aoki et al. Phys. Rev. Lett. **91**(2003)067003.

[2]E.Matsuoka et al. 28a3 of this meeting