

Effect of La substitution in $\text{PrFe}_4\text{P}_{12}$ studied by dc magnetization

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The filled skutterudite $\text{PrFe}_4\text{P}_{12}$ exhibits a second-order phase transition (A phase) at $T_A=6.5$ K. The transition is believed to be due to antiferroquadrupolar (AFQ) order, but there are still many questions regarding the nature of the A phase; the angular dependence of the staggered magnetization and of the transition temperature T_A are not yet well understood by the AFQ transition scenario. On the other hand, it is known that another ordered state (B phase) appears in high magnetic field above 8 T when the magnetic field is applied along the [111] direction [1]. In order to obtain further information on these phases, we have examined the effect of nonmagnetic La substitution for Pr using dc magnetization measurements on single crystals of $\text{Pr}_{1-x}\text{La}_x\text{Fe}_4\text{P}_{12}$ with La doping $x = 0, 0.01, 0.05$, and 0.15 .

Figure 1 shows the temperature dependence of the magnetic susceptibility χ ($=M/B$) of $\text{Pr}_{1-x}\text{La}_x\text{Fe}_4\text{P}_{12}$. The χ data in the $x = 0$ sample indicates a sharp peak at $T_A=6.5$ K, due to the A phase transition. A similar anomaly is also found at 6.4 K in the $x = 0.01$ sample. In contrast, no peak is observable in the sample with $x = 0.05$, though a very broad anomaly is seen below 6 K. This indicates the disappearance of the long-range A phase order at $x \approx 0.05$, consistent with specific heat measurements [2]. The effect of La substitution in $\text{PrFe}_4\text{P}_{12}$ is very different from that in the cubic compound CeB_6 , which exhibits an AFQ transition in a rather wide range of La doping $0 < x < 0.3$. This may reflect the importance of Fermi surface nesting on the A phase transition in $\text{PrFe}_4\text{P}_{12}$. For $x = 0.15$ the χ data increases smoothly down to about 2 K and saturates at lower temperatures. In isothermal magnetization curves, we find strong evidence for a ferromagnetic order at $x = 0.05$ and 0.15 . This observation suggests that the $\Gamma_4^{(1)}$ triplet state is located in the vicinity of the ground state.

[1] T. Tayama *et al.*: J. Phys. Soc. Jpn. **73** (2004) 3258.

[2] T. Namiki *et al.*: Physica B **312-313** (2002) 825.

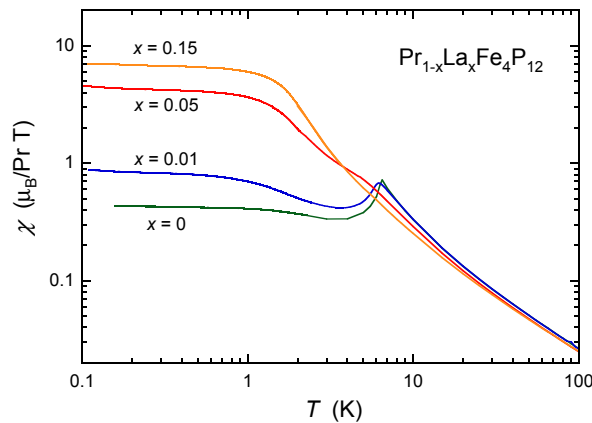


Figure 1: Log-log plot of the temperature dependence of the magnetic susceptibility χ ($=M/B$) of $\text{Pr}_{1-x}\text{La}_x\text{Fe}_4\text{P}_{12}$ with $x = 0, 0.01, 0.05$, and 0.15 . The data were obtained in a magnetic field of 0.1 T applied along the [100] direction.