Crystal structure and thermodynamic properties of the non-centrosymmetric $PrRu_4Sn_6$ caged compound

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Abstract. $PrRu_4Sn_6$ is a tetragonal, non-centrosymmetric structure compound. It is isostructural to the extensively studied Kondo insulator $CeRu_4Sn_6$ which crystallizes in the YRu_4Sn_6-type structure with space group $I\bar{4}2m$. In this structure, the Pr atom fills the void formed by the octahedral Ru_4Sn_6 units which results in a tetragonal body-centred arrangement. Here we present reports on the physical and magnetic properties of $PrRu_4Sn_6$. The temperature dependences of specific heat, $C_p(T)$, electrical resistivity, $\rho(T)$, and magnetic susceptibility, $\chi(T)$, reveal the absence of a long-range magnetic ordering down to 2 K. $\chi(T)$ follows a Curie-Weiss behaviour above 100 K with an effective magnetic moment, $\mu_{\text{eff}} = 3.34\ \mu_B$/Pr and paramagnetic Weiss temperature, $\theta_p = -19.47$ K indicating a dominant antiferromagnetic interaction. The magnetization at 2 K is quasi-linear in nature and attains a value of 0.86 μ_B/Pr at 7 T which is well reduced compared to the calculated value of 3.32 μ_B/Pr expected for a free Pr^{3+} ion. This is attributed to possible magneto-crystalline anisotropy in the system. $C_p(T)$ indicates the presence of a optical-phonon mode which is supported by a glass-like thermal conductivity above $\sim$45 K. This observation is associated with caged structured compounds where the low-frequency optical-phonon mode of the guest atom interacts with the host lattice, resulting in the scattering of heat-carrying quasiparticles.

1. Introduction

The $R Ru_4Sn_6$ (R = Y, La-Nd, Sm, Gd-Ho) series are intermetallic compounds which crystallize in the tetragonal YRu_4Sn_6-type structure with a non-centrosymmetric space group $I\bar{4}2m$ (No. 121) [1]. The structure was first reported by Venturini *et al* [2]. The crystal structure is made up of an octahedral Ru_4Sn_6 unit enclosing the guest R atom. Crystal structures of this nature have generated much interest lately especially in the search for new superconductors [3, 4]. Also, the non-centrosymmetric nature of the space group is characteristic of certain superconductors where the mixing of the spin-singlet and spin-triplet Cooper pairing channels have been found to give rise to a two-component order parameter [5–7]. $CeRu_4Sn_6$ is a Kondo insulator, and it is the most extensively studied member of the series [8–11]. Other studies by Koch and Strydom reveal a magnetic ordering for the isostructural compounds of $R Ru_4Sn_6$, with R = Sm, Gd and Dy compounds at low temperatures while those of Nd, Tb and Ho compounds are paramagnetic down to 2 K [12].

As part of our search for Pr-based systems exhibiting novel ground states, we have synthesized a polycrystalline sample of $PrRu_4Sn_6$ and investigated its physical and magnetic properties. It is noted that the existence of $PrRu_4Sn_6$ was first reported by Zumdick and Pöttgen [1] but no

102.8(2) $\mu\Omega$ cm, $K = 90.19(1)$ $\mu\Omega$ cm K, and $\Theta_R = 39.20(1)$ K are obtained from the least-square fit.This observation here further supports a metallic behaviour of $PrRu_4Sn_6$.

6. Conclusion

We have studied the physical and magnetic properties of the non-centrosymmetric $PrRu_4Sn_6$ compound. A paramagnetic ground state is inferred from the magnetic susceptibility results down to 2 K. The presence of low-frequency Einstein modes are observed in $C_p(T)$. This observation is further supported by the glass-like thermal conductivity for temperatures above 45 K. $S(T)$ undergoes a change in slope at $\sim$ 145 K, which is around the same temperature an anomaly in $C_p(T)$ is observed. Further measurements are expected to help clarify the origin of the observations in $C_p(T)$ and $S(T)$.

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