Possibility of Non Fermi Liquid Like States Co-exists With Superconductivity in Doubly Filled Skutterudites

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Abstract. Skutterudites is known to have fascinating ground states depending upon the void filling. Heat capacity of partially filled $Pr_{0.8}Pt_4Ge_{12}$ and doubly filled $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ skutterudites has been investigated. Superconducting gaps have been quantified through heat capacity in the presence of magnetic fields. C/T versus T^2 plot of $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ shows an upturn at low temperatures and this tendency increases with magnetic field, suggesting the possibility of a field induced NFL like states due to magnetic correlations co-existing with superconductivity.

Keywords: Transport properties, skutterudites, Non Fermi liquid.

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INTRODUCTION

The chemical composition of the filled skutterudite is RM_4X_{12}, where R are the lanthanides like Pr,Ce,Nd etc, M= Transition metal Fe,Co,Rh,Ru,Os,Pt and X=P,As,Sb,Ge. The filled skutterudites crystallize in the body centered cubic structure in the space group Im3. There are eight cubes in one unit cell, out of which two are voids, which can be occupied by filler atoms. The filler atoms are loosely bounded to the crystal and hence the rattling of these atoms can incoherently scatter the phonons, there by decreasing thermal conductivity. These materials utilized in thermoelectric power applications because of less thermal conductivity. The physical properties of skutterudites depend on their filler atoms. Superconductivity has been observed in $(La/Pr)Pt_4Ge_{12}$ skutterudites with a T_c of 8K [1]. $NdPt_4Ge_{12}$ is not a superconductor, instead they are valence fluctuating and antiferromagnetic in nature [2]. In this paper we have investigated the magnetic field dependent heat capacity of partially filled $Pr_xPt_4Ge_{12}$ and doubly filled $(Pr,Nd)Pt_4Ge_{12}$ superconducting Skutterudites and results are discussed in the light of with our earlier studies [3].

EXPERIMENTAL DETAILS

Polycrystalline samples $Pr_{0.8}Pt_4Ge_{12}$ and $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ were prepared using Argon arc melting followed by annealing at 800C for 12 days. The samples were characterized to be single phase by X-ray diffraction. Heat capacity is measured using QD-PPMS.

RESULTS AND DISCUSSIONS

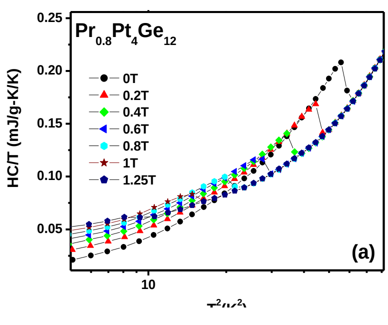

Fig 1. (a) Heat capacity down to 2K in field upto 1.25T for $Pr_{0.8}Pt_4Ge_{12}$.

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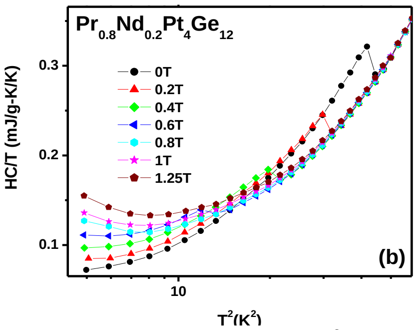

Fig 1. (b) Heat capacity down to 2K in field upto 1.25T for $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ respectively.

The low temperature heat capacity results of $Pr_{0.8}Pt_4Ge_{12}$ and $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ are shown in the figures. The zero field specific heat show jumps at 7.66K for $Pr_{0.8}Pt_4Ge_{12}$ and at 6.69K for $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ as shown in fig1(a) and fig1(b) . As we apply the field, the jump for superconducting transition shifts towards lower temperatures. The superconducting transition temperature decreases as one goes from $Pr_{0.9}Pt_4Ge_{12}$ to $Pr_{0.8}Pt_4Ge_{12}$ i.e 7.8 K to 7.66 K. The superconducting transition decreases very rapidly with Nd doping i.e 7.23K to 6.69K for $Pr_{1-x}Nd_xPt_4Ge_{12}$ (x = 0.1, 0.2). This can be understood if the low temperature heat capacity results of $Pr_{0.8}Pt_4Ge_{12}$ and $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ are compared with our previous reported results on $Pr_{0.9}Pt_4Ge_{12}$ and $Pr_{0.9}Nd_{0.1}Pt_4Ge_{12}$ [3].

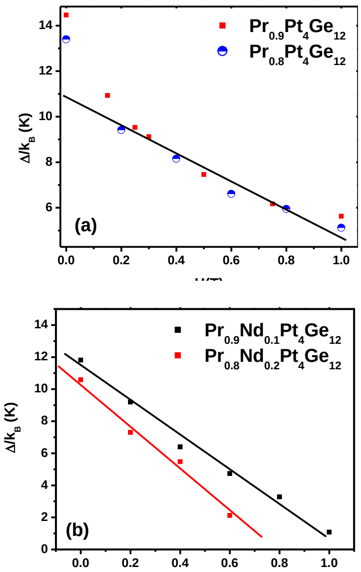

Fig 2. (a) Δ/k_B vs H(T) of $Pr_{0.8}Pt_4Ge_{12}$ and $Pr_{0.9}Pt_4Ge_{12}$ in field upto 1T (b) Δ/K_B vs H(T) of $Pr_{0.9}Nd_{0.1}Pt_4Ge_{12}$ and $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ in field upto 1T.

In the superconducting state specific heat can be written as : $C_s = A\,.\ \exp(-\Delta/k_BT)+\beta T^3$, where Δ is an energy gap. The calculated Δ/k_B values for all four samples in different magnetic fields are plotted and shown in fig(2). The values of calculated Δ/k_B for different magnetic fields are falling almost on same line for $Pr_{0.9}Pt_4Ge_{12}$ and $Pr_{0.8}Pt_4Ge_{12}$ samples. $Pr_{1-x}Nd_xPt_4Ge_{12}$ (x = 0.1, 0.2) samples show less Δ/k_B compared to $Pr_xPt_4Ge_{12}$. Energy gap decreases as the Nd doping is increased for $Pr_{1-x}Nd_xPt_4Ge_{12}$ system. Energy gap falls very rapidly with magnetic field for $Pr_{1-x}Nd_xPt_4Ge_{12}$ samples as compared to the $Pr_xPt_4Ge_{12}$. C/T versus T^2 plot of $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ shows upturn at low temperature and this upturn increases with magnetic field. The magnitude of low temperature upturn is higher for $Pr_{0.8}Nd_{0.2}Pt_4Ge_{12}$ compared to the $Pr_{0.9}Nd_{0.1}Pt_4Ge_{12}$ sample [3], which indicates that the magnetic correlations become stronger with Nd doping. Enhancement of magnetic correlations with Nd doping leads decrement of superconducting transition temperature and superconducting energy gap. The low temperature upturn indicates the possibility of field induced NFL like states co-exits with superconductivity. Observation of NFL at higher fields has also been observed in system like $CeIrIn_5$ due to metamagneitc quantum critical point [4]. This needs to be probed further for any fruitful conclusion.

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REFERENCES

1. R.Gumeniuk et al, PRL 100, 017002 (2008).
2. M Nicklas et al , arXiv:1007.3844v1 [cond-mat.str-el] 22 Jul 2010.
3. Swati Pandya et al, DAE-SSPS 2009, pp.
4. C.Capan et al, Phys.Rev.B 70, 180502(R) (2004).