Magnetic and Physical properties of the layered compound $Ce_3Os_4Al_{12}$

R. F. Djoumessi, B. N. Sahu, A. M. Strydom

Highly Correlated Matter Research group, Physics Department, University of Johannesburg, Auckland Park, South Africa

Introduction

$R_3T_4X_{12}$ type of compounds are of particular interest among intermetallics because the crystal structure contains layers as well as triangular and distorted Kagomé lattice features [1-3]. The arrangement of the atoms carrying magnetic moments at the vertices of the structure and the competition between ferro- and antiferromagnetic interactions can lead to the appearance of magnetic frustration phenomena. For instance, In $Gd_3Ru_4Al_{12}$, geometrical frustration together with the formation of ferromagnetic trimers due to the long-range RKKY interaction is observed at low temperatures [4]. Several studies have been done on Ru-based compounds in this series of aluminides. However, no physical and magnetic properties have been reported yet on Os-based compounds (except on $Gd_3Os_4Al_{12}$) synthesized for the first time by Niermann [5]. This work is the first report on physical properties of $Ce_3Os_4Al_{12}$ with the focus on the possible effects of the geometric frustration.

Experimental

The metals used as starting materials were cerium (solid bar, 99.99 mass% purity), Osmium (powder, 99.9+ mass% purity), and Aluminium (granules, 99.999 mass% purity). A polycrystalline sample of 1.5 g, was prepared by arc-melting under the argon atmosphere in an Edmund Bühler arc-melting furnace. After melting the sample was annealed in a resistance furnace at 900 °C for two weeks and finally water quenched. Powder x-ray diffraction was performed on a powdered specimen using the Rigaku diffractometer with Cu-Kα radiation. Data of physic properties were recorded using a Dynacool physical ar magnetic properties measurement system from Quantu Design (San Diego).

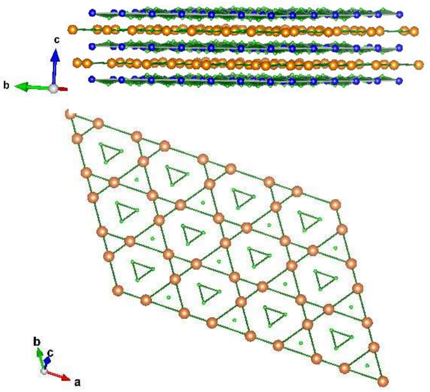

Fig. 1. (a): Layered representation of the crystal structu $Ce_3Os_4Al_{12}$ with Ce (Orange spheres), Os (blue spheres) ar (green). (b): The Ce_3Al_4 layer showing the distorted Kag nets.

Results

Formation and structure. The powder x-ray diffraction spectrum of this sample was successfully refined on the basis of the hexagonal $Gd_3Ru_4Al_{12}$ structure type with $P6_3/mmc$ space group. The obtained lattice parameters are a = 0.889 (1) nm and c = 0.953 (1) nm. These values are in good agreement with an earlier report [5]. The whole system is a layered structure. The R atoms are arranged as a distorted Kagomé net in the Ce_3Al_4 layer, and the Al atoms occupy two different sites in the Os_4Al_8 puckered layer (see Fig. 1).

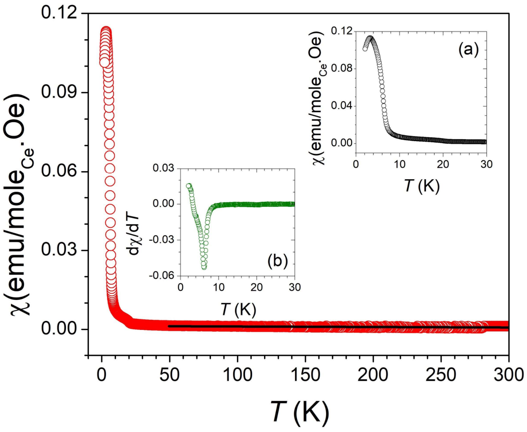

Fig. 2. Main panel: magnetic susceptibility of $Ce_3Os_4Al_{12}$ measured in a constant dc-magnetic field of 0.1 T. The black line represents the least-squares fit of the modified Curie-Weiss relation ($\chi(T) = \chi_0 + N_A\mu^2_{eff}/3k_B(T-\theta_p)$). The obtained positive paramagnetic Weiss temperature (θp = 5.33 K) indicates the dominant presence of ferromagnetic interactions in the high temperature region. The obtained effective magnetic moment (μ_{eff} = 0.94 μ_B/Ce) is around one third the full free-ion moment value 2.54 μ_B/Ce. Inset (a): highlight of the low-temperature region. Inset (b): represents the first derivative of $\chi(T)$. The sharp peak in the plot of $d\chi/dT$ indicates the presence of a magnetic phase transition.

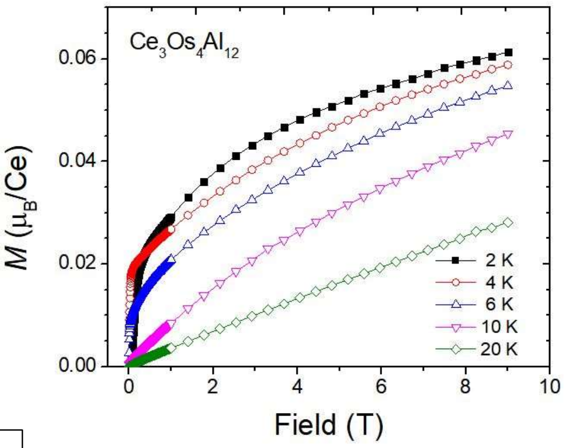

Fig. 3. Isothermal magnetization at temperatures between 2 K and 20 K. Broad curvatures are observed below 6 K with tendency to saturation at 9 T. The saturation magnetization is only about 0.06 μ_B/Ce which is considerably reduced compared to the free ion saturation value 2.16 μ_B/Ce. The quasi-linear behavior down to 6 K indicates a paramagnetic state.

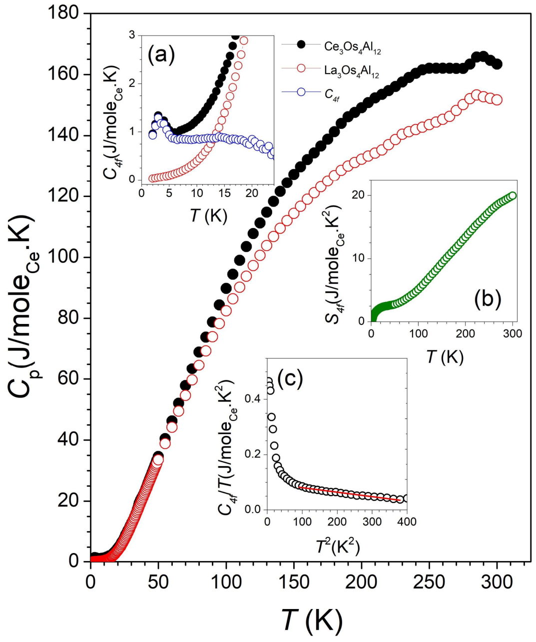

Fig. 4. Main panel: Specific heat of $Ce_3Os_4Al_{12}$ and $La_3Os_4Al_{12}$ against temperature. Inset (a) represents the low-temperature region. The blue symbols represent the magnetic contribution to the specific heat obtained by subtracting the specific heat of $La_3Os_4Al_{12}$ from that of $Ce_3Os_4Al_{12}$. The kink observed around the transition temperature T_c=3 K is a sign of a short-range order-like transition. Inset (b) shows the 4f contribution to the entropy per Ce as a function of temperature. The magnetic contribution released at T_c is about 0.6 J/mole$_{Ce}$.K^2 which is only a fraction of Rln2. A linear behavior observed from about 100 K to 300 K confirms that there is no tendency to saturation. Inset (c): specific heat $C_p(T)/T$ vs T^2. The red line represents a linear fit which gives an estimation of the Sommerfeld coefficient $\gamma = 0.097(1)$ J/ mole$_{Ce}$.K^2. This value is an enhancement of about 20 times over that of a normal metal.

References

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Conclusions

$Ce_3Os_4Al_{12}$ is a new example of layered Kagome structure with possible effects of the geometric frustration. The $\chi(T)$ and $C_p(T)$ data confirms the presence of a short-range order-like transition. A field study will be carried out further to confirm the nature of the transition.

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