Magnetic Properties of $Eu_xCa_{1-x}Fe_2As_2$ $(0 \le x \le 1)$ Superconductor

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Abstract

We have investigated evolution of magnetic properties of $Eu_xCa_{1-x}Fe_2As_2$ $(0 \le x \le 1)$ crystals at low-temperatures down to 2 K. Magnetic susceptibility increases while lowering temperature, showing a typical paramagnetic behavior. At low-temperature, there exists a sharp anomaly at T_N = 15 - 19 K, which arises due to the Eu^{2+} antiferromagnetic ordering. However, there is no clear evidence for the existence of spin-density wave (SDW) due to the Fe-moments. Temperature dependence of the susceptibility data is analyzed using the Curie-Weiss model and determined the Curie constant (**C**) and Weiss temperature (**θ**). It is found that both **C** and **θ** parameters vary linearly with increasing x. The obtained results will be compared with other published data.

Introduction

Recent discovery of a new class of iron-based superconductor (IBSC) in 2008 with the critical temperature up to 55 K has stimulated superconductivity research. In IBSC, the Fe-moments arranged in antiferromagnetic order and they appear as a spin-density wave (SDW) order. In general, the suppression of SDW either by doping or external pressure leads to an induction of superconductivity in these materials. There are different kinds of IBSCs, such as 1111, 122, 11, etc. Here, we have focused our studies in 122 family, namely $Eu_xCa_{1-x}Fe_2As_2$. Both $EuFe_2As_2$ and $CaFe_2As_2$ are the members of the 122-system in which the SDW order show up at $T_{SDW} \sim 190$ K and 170 K, respectively [1]. In addition, there exists another anomaly in $EuFe_2As_2$ at ~19 K due to Eu^{2+} antiferromagnetic order. At ambient pressure, both $CaFe_2As_2$ and $EuFe_2As_2$ samples do not show superconducting properties. While applying pressure, the SDW transition is gradually suppressed and superconductivity with $T_c \sim 10$ K is induced in $CaFe_2As_2$ and $T_c \sim 30$ K in $EuFe_2As_2$. In our recent report [2], we have investigated electrical transport properties of high-pressure $Eu_xCa_{1-x}Fe_2$. In this work, we have focused mainly on how magnetic properties of $CaFe_2As_2$ change upon Eu-doping.

Method

High-quality single crystals of $Eu_xCa_{1-x}Fe_2As_2$ were grown using the FeAs flux method as described in our previous report [2]. Magnetic properties were measured through a magnetic properties measurement system (MPMS, Quantum Design) with an applied field of 0.1 T along the c-axis. Magnetic susceptibility data are analyzed using the Curie-Weiss model. According to this law, the temperature dependence of the magnetic susceptibility (χ) is given by

$$\chi(T) = \frac{C}{T-\theta}, \qquad (1)$$

where χ (T) is magnetic susceptibility at temperature T, **C** is the Curie-Weiss constant, and **θ** is the Weiss temperature.

Results and Discussion

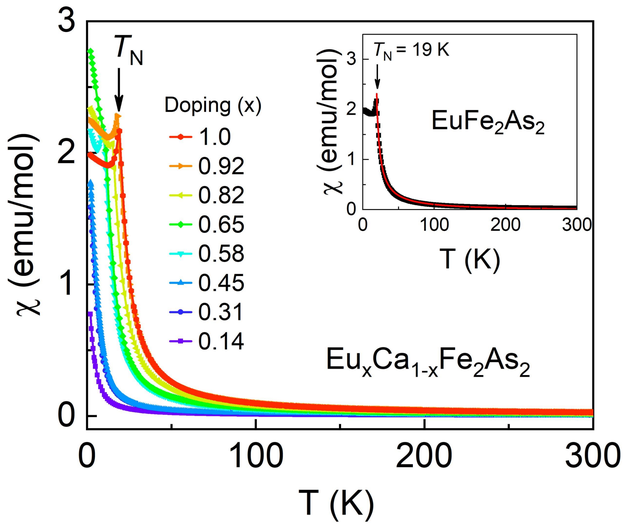

Figure 1. Magnetic susceptibility (χ) vs. temperature plot for $Eu_xCa_{1-x}Fe_2As_2$. χ(T) increases gradually while decreasing temperature. In higher x, there exist a sharp anomaly at $T_N \sim$ (15 - 19 K), which arises due to Eu^{2+} antiferromagnetic spin ordering, as indicated by the arrow. Inset: χ (T) data for the $EuFe_2As_2$ (x = 1) sample showing T_N. The red curve is the best-fit curve using the Curie-Weiss model (Eq. [1]).

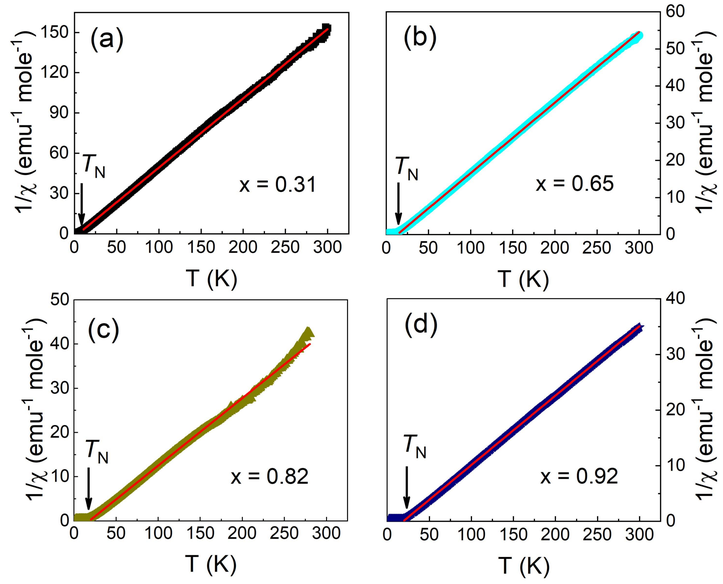

Figure 2. Inverse susceptibility, $1/\chi$ vs. Temperature graphs for $Eu_xCa_{1-x}Fe_2As_2$ samples at (a) x = 0.31, (b) x = 0.65, (c) x = 0.82, and (d) x = 0.92. $1/\chi$ increases linearly with temperature, consistent with the Curie-Weiss behavior. The arrow shows the Eu^{2+} antiferromagnetic order. The solid red lines are the best-fit lines using the Curie-Weiss law [Eq. (1)].

Results and Discussion

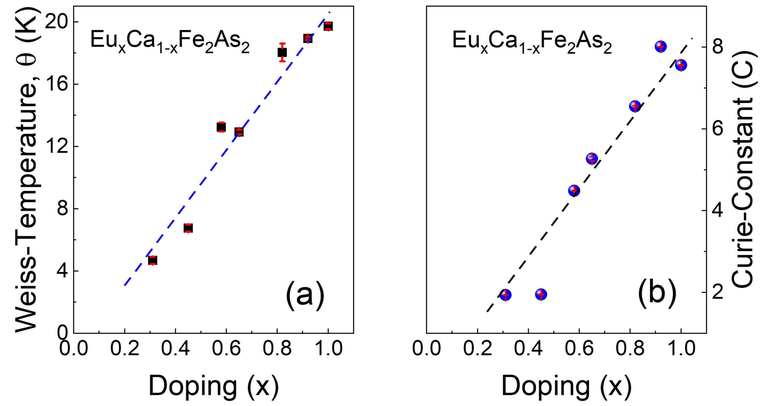

Figure 3. The best fit parameters, (a) **θ** (K) and (b) **C** plotted as a function of x. Both parameters vary almost linearly with x, as shown by the dashed lines.

Summary

- We have investigated the magnetic properties of $Eu_xCa_{1-x}Fe_2As_2$ samples. Susceptibility (χ) of all the samples show the Curie-Weiss behavior, i. e., that $1/\chi$ varies linearly with temperature.
- χ (T) does not show any evidence of the spin-density wave transition due to Fe-moments. However, there exists an anomaly due to the antiferromagnetic spin ordering of Eu^{2+} spins.
- We have analyzed the χ (T) data using the Curie-Weiss model. The best-fit parameters, the Weiss-temperature (**θ**) and Curie constant (**C**) vary almost linearly with the Eu-doping content.

References

1. L. Harnagea, *et al*., J. Phys.: Condens. Matter **30** 415601 (2018).
2. K. Shrestha, *et al*., Supercond. Sci. Technol. **33** 095010 (2020).

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