Investigation of the High-Field Magnetic Phase Diagram of $URu_{2-x}Fe_xSi_2$

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Introduction

The search for the order parameter of the hidden order (HO) phase in URu_2Si_2 has continuously attracted an enormous amount of attention. The HO phase occurs below T_0 = 17.5 K and coexists with superconductivity below T_c = 1.5 K [1]. The presence of a small antiferromagnetic moment of only ~0.03 μ_B/U in the HO phase that is too small to account for the entropy of ~0.2Rln(2) associated with the observed specific-heat anomaly. The HO phase exists in close proximity with the large moment antiferromagnetic (LMAFM) phase that arises for pressures larger than $P_c \geq$ 0.5-1.5 GPa [2]. Hereby many studies suggest that the HO and LMAFM phases are intimately related, and that a detailed their competition will be useful in unraveling the nature of the HO order parameter [1]. We have recently demonstrated that tuning URu_2Si_2 by chemical substitution of Fe with Ru offers an opportunity to study the competition between the HO and LMAFM phases [3]. Notably, the substitution of the smaller Fe ions for Ru ions in URu_2Si_2 acts as "chemical pressure" and reproduces the applied pressure phase diagram as demonstrated by measurements of the electrical resistivity, specific heat, and magnetization on polycrystalline samples. Our measurements on $URu_{2-x}Fe_xSi_2$ reveal that the HO-LMAFM transition at 1.5 GPa in URu_2Si_2 occurs at $x \approx 0.2$ ($P_{ch} \approx$ 1.5 GPa) in $URu_{2-x}Fe_xSi_2$. We have further performed preliminary experiments on single crystals samples by means of neutron diffraction that the magnetic moment indeed changes significantly above $x \approx 0.2$ supporting that tuning by Fe substitution acts as chemical pressure. Our new results therefore provide a unique opportunity to shed light on the LMAFM phase and its relationship to the elusive HO phase.

Experimental

As a first step we have investigated the high-field phase diagram of single crystals of $URu_{2-x}Fe_xSi_2$ with x=0.1 and 0.25 and a standard pulsed magnet available at the NHMFL pulsed field facility at LANL in magnetic fields up to 60 T using the standard magnetization setup. The measurements have been performed down to 3He base temperature of approximately 0.35 K.

Results and Discussion

Our main results is illustrated in Figure 1, and shows magnetization vs magnetic field H at T = 0.35 T for both concentrations. The magnetization curve for the x = 0.1 sample that is presumably still in the HO phase shows a two-step structure between 36 and 42 T. This behavior is indeed reminiscent of the undoped sample where this two-step structure was associated with the suppression of the HO phase and a metamagnetic transition [4]. For the x = 0.25 sample was concluded to exhibit a LMAFM phase from our previous measurements shows indeed completely different behavior with a small kink at 25 T and a step leading to saturation above 40 T.

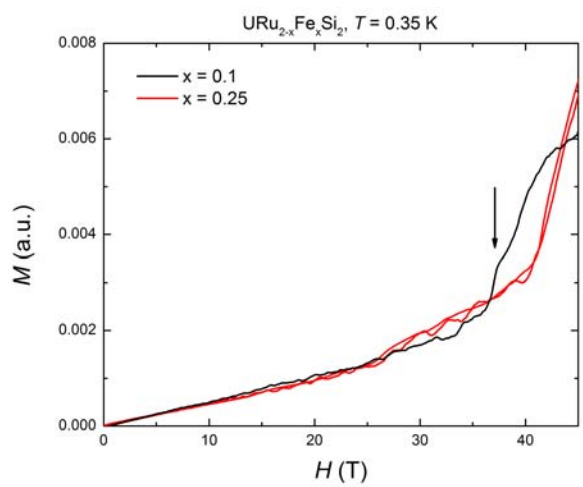

Fig. 1. Magnetization M vs. magnetic field H for $URu_{2-x}Fe_xSi_2$ at T = 0.35 K for x = 0.1 and 0.25. The x = 0.2 curve shows a two-step structure as marked by the arrow.

Conclusions

Our results suggest that the HO-LMAFM transition indeed exist between x = 0.1 and 0.25 in agreement with our previous measurements on polycrystalline samples [3].

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References

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