Effect of chemical pressure on the magnetic order in heavy electron system $CeRhIn_5$ —^{115}In NQR study of $CeRh_{1-x}Ir_xIn_5$—

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Abstract

We have studied the chemical-pressure effect on the Neel temperature (T_N) due to the substitution of Ir for Rh in the layered heavy fermion compound $CeRhIn_5$ by nuclear quadrupolar resonance (NQR) technique. We find that T_N increases slightly upon replacing Ir for Rh. This feature resembles that in hydrostatically presurized $CeRhIn_5$ below 1.0 GPa where T_N shows a similar dependence against pressure.

Key words: heavy fermion; $CeRhIn_5$; $CeIrIn_5$; NQR

1. Introduction

In many heavy mass f-electron systems, two major interactions, the long-range RKKY (Ruderman-Kittel-Kasuya-Yosida) interactions between f-electrons and the Kondo interaction between f-orbit and conduction electrons, compete with each other. Since the RKKY and Kondo interactions have a distinct dependency on the magnetic exchange coupling which can be tuned by applying hydrustatic or chemical pressures, a system can usually be tuned to undergo a quantum phase transition from a magnetically ordered state to a non-magnetic state. Around the magnetic quantum critical point (QCP), many unusual properties such as non-Fermi liquid behavious are observed. The most interesting phenomenon is the appearance of superconductivity. $CeRhIn_5$ is a newly found heavy fermion compound [1]. The unit cell consists of a layer of $CeIn_3$, which itself is a heavy fermion compound [2], and a $RhIn_2$ block. The system orders antiferromagnetically at ambient pressure at T_N=3.8 K, with an incommensurate, spiral spin structure along the c-axis [3]. When Rh is replaced completely by Ir, the compound $CeIrIn_5$ becomes a superconductor [4], with an anisotropic superconducting gap [5]. It is interesting to investigate how the electronic structure evoles in $CeRh_{1-x}Ir_xIn_5$ with continously changing the Ir content. Here we report an NQR study about the chemical effect on the Neel temperature caused by the Ir substitution .

2. Experimental Results and Discussion

Single crystals of $CeRh_{1-x}Ir_xIn_5$ were grown by In-flux method [4]. For NQR measurements, the crystals are ground to powders of modest particle size in order to make the high frequency field penetrate into the sample. NQR measurements were performed using a phase-coherent spectrometer. T_1 was measured by using the saturation-recovery method. There are two inequivalent crystalgraphic In sites in $Ce(Rh,Ir)In_5$, the In(1) site in the $CeIn_3$ plane and the In(2) site in the $(Rh,Ir)In_2$ block. The results reported below are all taken at the $\pm 3/2 \leftrightarrow \pm 5/2$ transition of the In(2) site around 32 MHz [5].

A typical example of the temperature dependence of $1/T_1$ is shown for x=0.35 in Fig. 1. Slightly above T=4

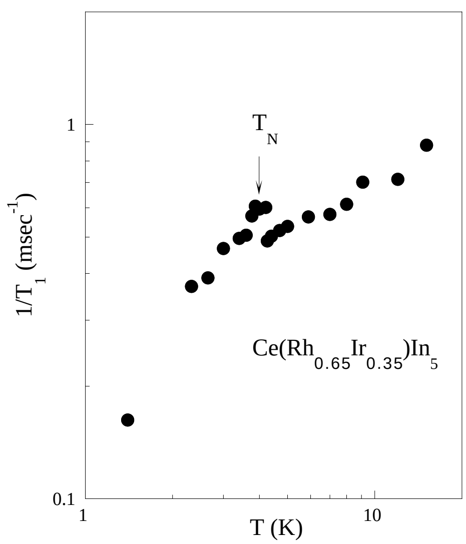

Fig. 1. Temperature dependence of the [115]In nuclear spin-lattice relaxation rate $1/T_1$ for $CeRh_{0.65}Ir_{0.35}In_5$ measured at the In(2) site in the $Ce(Rh,Ir)_2$ block.

K, $1/T_1$ increases with decreasing temperature, due to the slowing down of the magnetic moment toward the phase transition, then decrease rapidly. We define the Neel temperature T_N as the temperature at which $1/T_1$ shows a peak. Such determined T_N in $CeRhIn_5$ was in good agreement with that inferred from thermal and transport measurements [6,7].

In Fig. 2, the Neel temperature is shown as a function of Ir content, together with the superconducting transition temperature from Pagliuso *et al* [8]. It is seen that T_N increases slightly with increasing Ir content. This feature resembles that seen in $CeRhIn_5$ under hydrostatic pressure. This indicates that substitution of Ir acts as a chemical pressure in tuning the magnetic exchange coupling. Although it was suggested from the lattice compression that the substitution of Ir for Rh preduced a more uniaxial pressure along the c-axis [8], the content of x=0.35 is equivalent to the application of P=1.0 GPa of hydrostatic pressure in increasing T_N. The future work includes clarifying how superconductivity coexists with the magnetic order at x=0.35 which was suggested by transport measurements [8].

In summary, we have carried out [115]In NQR measurements in $CeRh_{1-x}Ir_xIn_5$ for x=0, 0.25 and 0.35. The spin lattice relaxation rate indicates that T_N increases upon increasing Ir content. This result resembles that observed in hydrostatically pressurized $CeRhIn_5$ where T_N shows a similar dependence against pressure below P=1.0 GPa, suggesting that substituting Ir for Rh is equivalent to applying pressure.

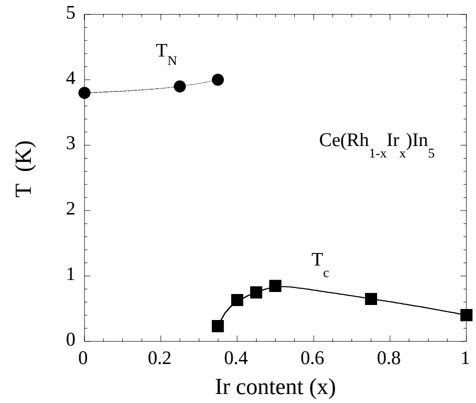

Fig. 2. Ir content dependence of the Neel temperature T_N in $CeRh_{1-x}Ir_xIn_5$. The superconducting transition temperature is from Pagliuso *et al* [8]

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