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Magnetic resonance imaging of LaFeAsO0.4H0.6 at 3.7 GPa

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Abstract: When x is greater than or equal to 0.49, the typical superconductor LaFeAsO1−xHx, which is doped with electrons and based on iron, enters an antiferromagnetic (AF) phase. Our goal in conducting these nuclear magnetic resonance (NMR) experiments was to study the magnetic properties close to a pressure-induced quantum critical point (QCP) in LaFeAsO0.4H0.6 at 3.7 GPa. It seems that the spin moments are still organised at 3.7 GPa, as the 1H-NMR spectra exhibit a broadening of the linewidth at temperatures below 30 K. Based on the relaxation time T1 of 75As, it was established that gapped and gapless spin excitations may coexist in the ordered state. Based on the pressure dependence of the gapped excitation, the pressure-induced QCP is predicted to be 4.1 GPa.

I. Introduction

A prototypical electron-doped iron-based pnictide $LaFeAsO_{1-x}H_x$ (0 x 0.6) exhibits unique elec-tronic properties in a heavily carrier-doped regime:a superconducting (SC) phase with double-domes structure expands in a wide regime ($0.05 < x < 0.49$) [1] and an antiferromagnetic (AF) phase man-ifests itself by further H doping (0.49 x) [2–4]. Band calculations show that both Fermi surfaces and nesting vectors change by H doping: the two hole pockets present at Γ point in the lightly H- doped regime almost disappear in the heavily H doped regime [5, 6]. The change in the nesting vec- tors due to H doping would cause a change in wave-vector (q) dependent spin susceptibility $\chi(q, \omega)$ and would allow for the appearance of two AF phasesin the lightly and heavily H-doped regimes.

The AF phase in the heavily H-doped regime is strongly suppressed upon applying pressure [7]. Wehave performed nuclear magnetic resonance (NMR)measurements on $LaFeAsO_{0.4}H_{0.6}$ at 3.7 GPa, and we have found that the spin excitation gap appear- ing at the AF phase vanishes at around 4.1 GPa.We have investigated the magnetic properties in the vicinity of a pressure-induced quantum critical point (QCP)(▪4.1 GPa).

II. Experimental apparatuses andconditions

A pressure of 3.7 GPa was applied using a NiCrAl- hybrid clamp-type pressure cell as shown in Fig. 1 [8]. We have used a mixture of Fluorinert FC-70 and FC-77 as the pressure-transmitting medium.A coil wounded around the powder samples and anoptical fiber with the Ruby powders glued on top

Figure 1: A NiCrAl-hybrid clamp-type pressure cell [8]. A coil wounded around the powder samples and an op-tical fiber with the Ruby powders were inserted into the sample space.

were inserted into the sample space of the pressurecell [8]. The size of the coil was 2.4 mm in di-ameter and 3.5 mm in length, and the number of windings was 18 turns. The pressure was monitored through Ruby fluorescence measurements. The R1 and R2 lines at ambient pressure, 3.0 and 3.7 GPa are shown in Fig. 2. The wavelength of the R1or R2 peak shifts linearly with respect to pressure. The shift of the wavelength $\Delta\lambda$ satisfies the relation P(GPa)=$\Delta\lambda(nm)/0.365$.

NMR measurements for the powder samples were acquired using a conventional coherent-pulsed NMR spectrometer. The relaxation rate ($1/T_1$) wasmeasured using a conventional saturation-recoverymethod for the samples whose FeAs planes are par-allel to the applied field.Figure 2: Ruby fluorescence spectra. The smaller and larger peaks correspond to the R2 and R1 transitions, respectively.

III. Experimental results

T_N . The behavior is not observed at ambient pres- sure and it is characteristic of the critical behav-ior near the pressure-induced QCP. The coexistenceof the gapped and gapless excitations are specificto this system. In this system, major Fermi sur- faces are electron pockets with a square-like shape in two dimensional k space. Some parts of the elec- tron pockets would contribute to the nesting and the SDW formation. The critical behavior wouldoriginate from the other parts of the Fermi sur-faces. The nesting condition becomes worse and the bandwidth becomes broader with increasing pres- sure. Owing to these effects, the activated behavior shown in Eq. (1) would disappear at the pressure- induced QCP.

IV. Conclusions

To study the magnetic characteristics close to the pressure-induced QCP, we conducted nuclear magnetic resonance (NMR) experiments on LaFeAsO0.4H0.6 at 3.7 GPa. The SDW ordered state is still at 3.7 GPa, as we have discovered. Based on the pressure dependence of the spin excitation gap, the pressure-induced QCP is predicted to be 4.1 GPa. Two types of excitation, one gapped and one gapless, are seen as the Curie-Weiss behaviour of 1/T1T, suggesting that the Fermi surfaces are separate places from which the two types of excitation arise.

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