High pressure μSR study of quantum phase transition in CeNiAsO

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The discovery of superconductivity in $LaFeAsO_{1-y}F_y$ systems[1)] triggers not only a new search of the iron-based superconductors, but also studies of the Kondo effect when La is replaced by magnetic ions such as Ce. The Fe $3d$ electrons in such systems usually undergo a spin-density-wave (SDW) transition at about 140 K on top of the much lower temperature where the $4f$ electrons become magnetically ordered.[2)] In order to study the $4f$ electronic properties, we therefore focused on a Ni-based compound, namely, CeONiAs, instead of Fe-based compounds since the Ni ions are not long-ranged magnetically ordered in these compounds, as observed by experiments and theoretical calculations.[3)]

Our previous studies including magnetic susceptibility, transport, and thermal dynamic measurements show that CeONiAs undergoes two successive magnetic transitions at $T_1 = 9.3$ K and $T_2 = 7.3$ K, respectively, and these two transitions can be suppressed both by hydrostatic and chemical pressures (P). When $P > 4$ kbar, T_1 can be hardly seen, while T_2 is continuously suppressed with a critical value of $P_c \sim 6.3$ kbar. Resistivity measurements indicate that there is a quantum phase transition at P_c. In order to reveal the role of magnetic correlations around the quantum critical point (QCP), and the evolution of magnetic structure with pressure, we have performed μSR experiments with gas pressures up to 6.1 kbar on $CeONiAs_{0.9}P_{0.1}$, where the substitution of As by P is expected to reduce P_c.

During the high pressure μSR measurement, most of the muons are stopped at the pressure cell made of Cu, and therefore, muon spin precession is hardly observed even when magnetic ordering appears in the sample, which limits our analyses of the evolution of the magnetic structure with pressure from the observation of muon spin precession in the zero field (ZF) measurement. Alternatively, we performed transverse field (TF) measurements and the spectra were fitted using the following function:

$$A(t) = A_{\rm ini}\cos(\gamma_\mu Bt + \varphi)\exp(-\lambda t) \quad (1)$$

where $A_{\rm int}$ is the initial asymmetry, γ_μ is the muon gyromagnetic ratio, B is the magnetic field, and λ is the muon spin relaxation rate.

Figure 1(a) shows the temperature dependence of the initial asymmetry, $A_{\rm ini}$ at ambient pressure (A.P.) and $P = 6.1$ kbar. At A.P., $A_{\rm ini}$ is nearly temperature independent at high temperatures, and decreases sharply below approximately 10 K. No further significant change is observed below 10 K due to the low signal-to-background ratio. The transition temperature is suppressed to approximately 6 K when $P = 6.1$ kbar. Fig. 1(b) shows the temperature dependence of the muon spin relaxation rate λ. The substantial increase of λ below about 10 K and 6 K, respectively, at A.P. and $P = 6.1$ kbar is consistent with the results of the temperature dependence of $A_{\rm ini}$. The appearance of the internal field will increase the internal field distribution width at the muon site, thus enhancing the muon spin relaxation rate. Owing to the usage of a pulsed muon source, the increase in muon spin relaxation rate will usually lead to a decrease in the initial asymmetry. Thus, our current results confirm the magnetic ordering from the microscopic view point. The application of high pressures up to 6.1 kbar also confirms that the magnetic ordering is suppressed by pressure. Unfortunately, valuable information about the evolution of the internal field with the pressure cannot be obtained since we cannot observe the muon spin precession directly as mentioned above.

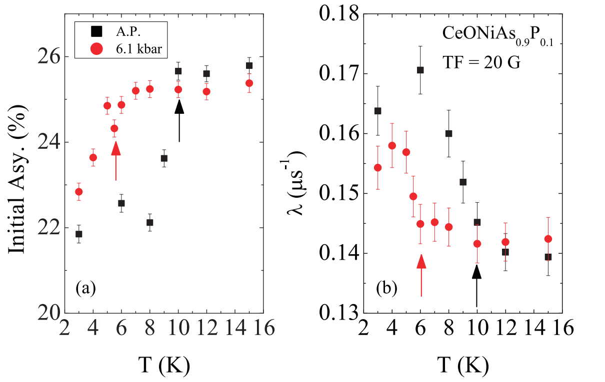

Fig. 1. Temperature dependence of the extracted parameters. (a) The initial asymmetry. (b) The muon spin relaxation rate, λ. The arrows indicate the magnetic transition temperatures.

References

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