Muon spin relaxation study of spin-glass freezing in the Heusler compound $Ru_{1.9}Fe_{0.1}CrSi$†

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The magnetic properties of the Heusler compounds $Ru_{2-x}Fe_xCrSi$ have attracted interest. It has been revealed that Fe-rich compounds are ferromagnetic[1)] and that the Ru-rich compound Ru_2CrSi shows an antiferromagnetic transition at $T_N = 14$ K.[2)] Although the Ru-rich compound $Ru_{1.9}Fe_{0.1}CrSi$ was found to show a peak in magnetic susceptibility at $T_N^* \sim 30$ K, which seemed to indicate an antiferromagnetic transition, no phase transition was found around T_N^* or at any other temperatures in the specific heat.[3,4)] Instead, the difference between the magnetic susceptibilities observed in a zero-field-cooling process and a field-cooling process increased significantly below $T_g \sim 15$ K, which was regarded as the onset of strong irreversibility.[3)] This observation suggests the formation of a spin-glass (SG) state. In order to reveal the nature of the magnetic transitions, we have performed zero-field (ZF) and longitudinal-field (LF) muon-spin-relaxation (μSR) measurements for $Ru_{1.9}Fe_{0.1}CrSi$. The measurements were carried out at the RIKEN-RAL Muon Facility using a spin-polarized single-pulse positive surface muon beam. In these measurements the time spectra of muon spin depolarization consisted of two components, and the asymmetry, $A_0(t)$, can be expressed as

$$A_0(t) = A_1 \exp(-\lambda_1 t) + A_2 \exp(-\lambda_2 t). \quad (1)$$

The first and second terms represent the fast and slow relaxation components, respectively, and λ_1 and λ_2 are the muon spin relaxation rates for each component. The initial asymmetry A_0 is $A_0(0) = A_1 + A_2$.

The parameters in Eq. (1) were obtained from the fitting of the time spectra, and these temperature dependences in the ZF-μSR measurement are shown in Fig. 1. As shown in the figure, a peak of the relaxation rates was observed at ∼16 K, and this suggests the onset of spin freezing at $\sim T_g$. Furthermore, LF-μSR measurement for different values of magnetic field was performed at 0.3 K, which confirmed the presence of a static internal magnetic field. The internal field was estimated to be approximately 0.1308 ± 0.005 T. From these results we conclude that SG freezing occurs at T_g.

On the other hand, an anomaly in the relaxation rate of ZF-μSR, indicating a phase transition, appeared to be absent around T_N^*, whereas with decreasing temperature a large decrease in the initial asymmetry and a gradual increase in the relaxation rates were observed starting at ∼40 K, which is slightly higher than T_N^*. The loss of the initial asymmetry may have been caused by a static internal field. To investigate the origin of the large decrease in the initial asymmetry below ∼40 K, we performed LF-μSR measurements as a function of magnetic field H_{LF} between T_g and $\sim T_N^*$. The H_{LF} dependence of A_2 was analyzed, and it was found that at temperatures below 30 K, A_2 increases from approximately the same field as at 0.3 K. This analysis suggests that a static field arises at the muon site from temperatures higher than $T_N^* \sim 30$ K and the value of the static field does not change much below ∼30 K. These results indicate an inhomogeneous magnetic state. It appears that the formation of independent spin-frozen regions begins at ∼40 K. As the temperature decreases, these static regions extend gradually, and this results in the observed decrease in the initial asymmetry. The correlation between static regions becomes larger and eventually SG freezing occurs at T_g.

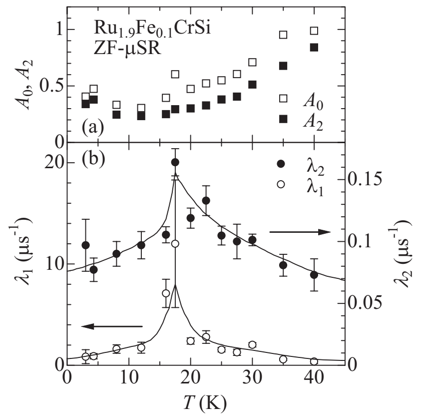

Fig. 1. Temperature dependences of (a) $A_0 = A_1 + A_2$ and A_2, and (b) λ_1 and λ_2, for ZF-μSR. Solid lines are guides to the eye.

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