Fast Muon Spin Relaxation in Ferromagnetism of Potassium Clusters in Zeolite A

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Periodically arrayed potassium clusters in zeolite A are known to show ferromagnetic properties [1]. In zeolite A, α-cages with the inside diameter of $\sim$ 11 Å are arrayed in a simple cubic structure. When guest K atoms are loaded into K-type zeolite A ($K_{12}Al_{12}Si_{12}O_{48}$), the guest 4$s$-electrons are shared among several K^+ ions and K clusters are formed in the α-cages. We can control the average number of electrons per cluster, n, up to $\sim$7.2. Ferromagnetism is observed at $2 < n < 6$. The origin of the spontaneous magnetization is explained by spin-canting of antiferromagnetism [2]. Previously, the magnetic phase transition was clearly detected in μSR study by using pulsed muons at RIKEN-RAL [3]. We also observed a remarkable decrease in the initial asymmetry below Curie temperature T_C. The analysis of such fast decay is limited in the pulsed muons. In the present study, we measured the fast decay component for the sample at $n = 4.5$ by using dc muons of GPS at PSI-SμS.

In the ZF-μSR spectra, the fast and slow relaxation and the precession components were clearly observed at low temperatures below $T_C \sim 7$ K. The fast relaxation was clearly seen within $\sim$ 0.1 μs. The spectra were well fitted by the following function:

$$A_1 \exp(-\lambda_1 t) + A_2 \exp(-\lambda_2 t) + A_3 \exp(-\lambda_3 t) \cos \omega t + B. \quad (1)$$

The fast and slow relaxation rates, λ_1 and λ_2, respectively, suddenly increase more than one order of magnitude below T_C. According to the decoupling behavior in the LF-μSR, the origin of these relaxations are assigned to a static internal field. The magnitude of the internal field estimated fromgλ_1 is $\sim$ 200 Oe. This value is very large, but the relaxation is easily decoupled by applying extremely weak LF of $\sim$ 10 Oe. This is not an ordinary decoupling behavior. The origin of the strong internal field cannot be explained by dipole field but may be by the Fermi contact interaction between muons and s-electrons of K clusters. Several stopping sites for positive muons have been proposed near oxygen of zeolite framework. The Fermi contact may be possible near the oxygen of the 8-membered ring in β cage side, because the repulsive potential for s-electrons is lower than that inside of double 4-ring. The anomalous LF-sensitivity in the decoupling can be well explained by considering the soft ferromagnetism of present spin-canting antiferromangetism, because an effective magnetic field from adjacent clusters at this middle site is easily oriented along the direction of external magnetic field.

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