Muon-spin relaxation study on Li- and Na-diffusion in solids

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Diffusion of Li^+ ions in solids is a basic principle behind the operation of Li-ion batteries. Although a diffusion coefficient of Li^+ (D_{Li}) in solids is usually evaluated by ^{7}Li-NMR, difficulties arise for materials that contain magnetic ions. This is because the magnetic ions contribute additional spin-lattice relaxation processes that are considerably larger than the $1/T_1$ expected from only Li diffusion. As a result, it is extremely difficult to estimate correct D_{Li} by Li-NMR, although D_{Li} is one of the primary parameters that govern the charge and discharge rate of a Li-ion battery, particularly in the case of a future solid-state battery.

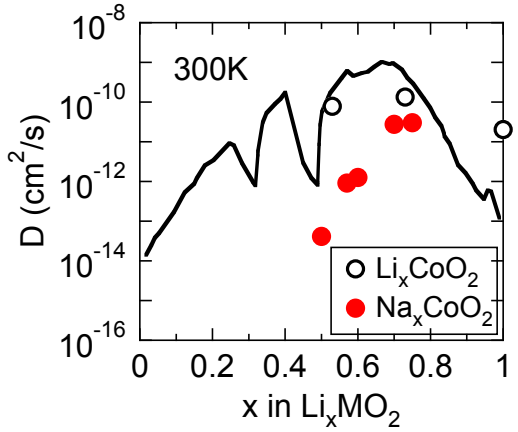

Fig. 1 The relationship between a diffusion coefficient of Li^+ and Na^+ (D_{Li} and D_{Na}) for Li_xCoO_2 and Na_xCoO_2 determined by μSR [1,3]. A solid line represents the prediction from first principles calculations for Li_xCoO_2 [A. Van der Ven and G. Ceder, Electrochem. Solid-State Lett. **3**, 301 (2000).].

We have, therefore, initiated to measure D_{Li} in solids with μSR [1]. Muons do not feel fluctuating magnetic moments at high T, but instead sense the change in nuclear dipole field due to Li diffusion. Even if magnetic moments still affect the muon-spin depolarization rate, such an effect is, in principle, distinguishable from that of nuclear dipole fields. In particular, a weak longitudinal field can be applied that decouples the magnetic and nuclear dipole interactions [2]. Here, we wish to summarize our μSR work on Li-diffusion and compare the μSR result with that obtained by NMR and other techniques. Furthermore, we wish to report the preliminary result to detect Na-diffusion in solids by μSR [3].

References

[1] J. Sugiyama et al., Phys. Rev. Lett. **103**, 147601 (2009); Phys. Rev. B **82**, 224412 (2010).

[2] R. S. Hayano et al., Phys. Rev. B **20**, 850 (1979).

[3] J. Sugiyama et al., in the Meeting Abstract of Phys. Soc. Jpn. **67-1** (2012) p. 588.