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

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Diffusion of Li\textsuperscript{+} ions in solids is a basic principle behind the operation of Li-ion batteries. Although a diffusion coefficient of Li\textsuperscript{+} ($D_{Li}$) 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.

We have, therefore, initiated to measure $D_{Li}$ in solids with $\mu$SR [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 $\mu$SR work on Li-diffusion and compare the $\mu$SR result with that obtained by NMR and other techniques. Furthermore, we wish to report the preliminary result to detect Na-diffusion in solids by $\mu$SR [3].

References