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# Direct measurement of nanoscale lithium diffusion in solid battery materials using radioactive tracer of 8Li

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The diffusion coefficient of lithium in solid materials used in secondary Li−ion batteries is one of key factors that determine the rate at which a battery can be charged and discharged. Nevertheless, reported lithium diffusion coefficients in Li battery materials measured with various methods are largely scattered over several orders of magnitudes, for example, 6 orders for LiCoO2 and 8 orders for LiMn2O4, which are commercially used as electrodes. The traditional radioactive tracer method with a serial sectioning technique can provide the most accurate diffusion coefficient in a direct way, but it cannot be applied for Li battery materials because of no availability of radioactive Li isotopes with a half-life suitable for such offline applications. We developed an in situ lithium diffusion tracing method using a short−lived radioactive ion beam of 8Li, with the half- life of 0.84 s, which immediately decays into two alpha particles. Tracing the time evolution of the changes in the energies of the alpha particles from diffusing 8Li, which is primary implanted into a sample of interest, we can extract Li diffusion coefficient directly. The method has been successfully applied to measure diffusion coefficients in Li ionic conductors (e.g. , [1]). The range of measurable lithium diffusion coefficient by the current method is from 10^-6 down to 10^-10 cm2/s. For measurements of Li diffusion coefficients in battery electrodes such as LiCoO2, it is required to improve the lower limit of the detection by this method.
We have proposed a new method by detecting alpha particles emitted from decaying 8Li at a small angle (10 degree) relative to a sample surface that is irradiated with a low—energy (8 keV) 8Li beam. The new method has been successfully applied to measuring Li diffusion coefficients for an amorphous Li4SiO4-Li3VO4 thin film, demonstrating that the new method is sensitive to diffusion coefficients down on the order of 10^-12 cm2/s, corresponding with nanoscale Li diffusion of several 10 nm/s [2]. Using the new method, measurements of Li diffusion coefficients in electrode materials such as LiMn2O4 are in progress. In this presentation, we will introduce recent experimental results of our newly developed nanoscale Li diffusion measurement.

[1] S. C. Jeong, et al., Solid State Ionics (2009) 180, 626.
[2] H. Ishiyama, et al., Jpn. J. Appl. Phys. (2014) 53, 110303.

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