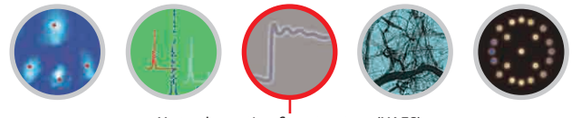
Development of Long-Life Next-Generation Li-Ion Batteries

Clarification of the causes of performance deterioration of Li-ion batteries

Research method



X-ray absorption fine structure (XAFS)

Beamline used at SPring-8: Sunbeam BM (BL16B2)

Award for this research: The Ceramic Society of Japan Award for Technical Development (2008)

Achievements

- Clarification of the causes of performance deterioration of next-generation **Li-ion batteries*** with a Ni oxide cathode at the atomic level by examining the charging and discharging processes
- Optimization of the composition of the cathode to suppress the **growth of the deteriorated layer** and to prolong the life of the batteries
- Paving the way to applying Li-ion batteries to hybrid and electric cars by the expected reduction of their weight and cost

R&D facility: Toyota Central R&D Labs., Inc.

***Li-ion battery:** a type of secondary battery that can be reused by charging. Li-ion batteries have been increasingly used in mobile electronic devices because of their lighter weight and greater capacity than Ni-Cd and Ni-MH batteries. Hybrid and electric cars also require long-life secondary batteries, and various R&D laboratories around the world are competing in the development of Li-ion batteries with improved performance.

Role of SPring-8

Background

Li-ion batteries in practical use utilize Co as the cathode material. Only a small amount of Co is produced worldwide, and it is therefore expensive, which increases the cost of batteries. There is now a demand for next-generation batteries that use inexpensive abundant materials.
A material mainly composed of Ni oxide has recently attracted attention as a new cathode material to replace Co. However, this material has the problems that the structure of the cathode particles changes and the battery performance deteriorates at an early stage with repeated charging and discharging. The elucidation of the causes of these problems is desired.

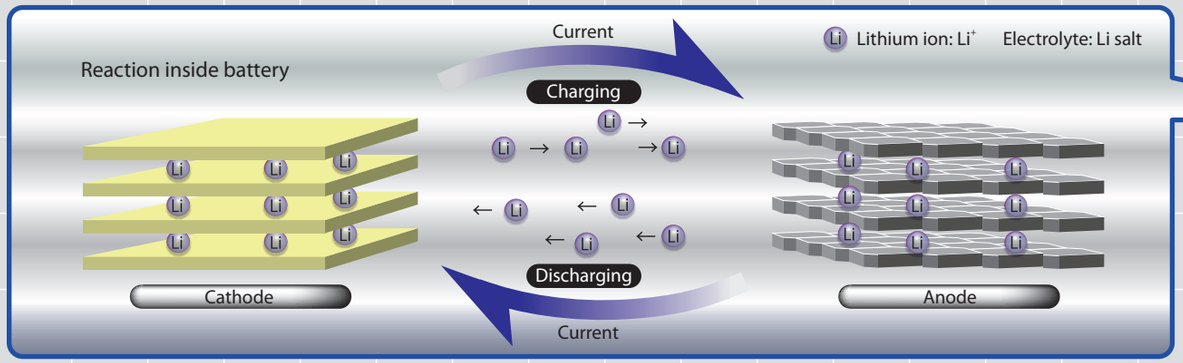
Results

The SPring-8 high-brilliance X-ray enables us to directly observe the states of cathode particles. As a result of observing a battery that was repeatedly charged and discharged, it was clarified that a deteriorated layer with decreasing transmission of Li^+ was grown on the surface of the cathode particles and that Ni^{2+} block the path of Li^+.
From the observation of batteries with different electrode compositions, we found a composition at which the formation of a deteriorated layer can be suppressed. Thus, the life of batteries was successfully prolonged.

Publication: T. Nonaka et al.; Journal of Electrochemical Society **154**, A353-A358 (2007)

Principle of Li-ion battery

A Li-ion battery comprises a cathode, an anode, an electrolyte, a separator, and other elements. The battery performance is determined by the cathode material, and $LiCoO_2$ is currently widely used. Graphite (C) is used for the anode and lithium salt for the electrolyte. During charging, the Li^+ in the cathode dissolve in the electrolyte and penetrate into the graphite structure of the anode. The opposite reaction occurs during discharging.



Mechanism underlying deterioration of battery performance

1) Growth of deteriorated layer
The actual cathode comprises cathode particles of a few μm diameter (secondary particles) surrounded by an electrolyte, each of which is an aggregate of a number of single-crystal particles (primary particles). It becomes increasingly difficult for the surface of these secondary particles to pass Li^+ upon repeated charging and discharging.

2) Deteriorated layer blocking path of Li^+
From the atomic-level observation, it was found that the path of Li^+ is blocked by Ni^{2+} that replace some of the Li^+ upon repeated charging and discharging.