Energy

# Development of new cathode materials for magnesium secondary battery

Yasushi IDEMOTO (Professor, Department of Pure and Applied Chemistry, Faculty of Science and Technology, Tokyo University of Science)

## Purpose of Research

In recent years, research on high-performance next-generation secondary batteries has been underway to address safety issues and limitations of electricity storage capacity. In particular, research is being conducted both in Japan and abroad on magnesium secondary batteries that use magnesium ions as mobile ions. Magnesium secondary batteries have the potential to achieve a high energy density, but to date no promising materials have been discovered as cathode materials for them. This research is aimed at exploring cathode materials for magnesium secondary batteries that have better characteristics than the cathode materials used for existing lithium-ion batteries.

## Summary of Research

Aiming to bring about more-advanced generation high-capacity secondary batteries that surpass lithium-ion batteries, we have successfully made new cathode materials for magnesium secondary batteries. These batteries are said to have the potential for a theoretical cathode capacity 1.5 times higher than lithium-ion batteries. We have developed two types of cathode active materials for magnesium secondary batteries: a spinel type (initial discharge (actual example): 439 mAh/g) and a rock-salt type (initial discharge (actual example): 160 mAh/g).

**Comparison of cathode material performance between magnesium secondary batteries and lithium-ion batteries**

| Battery | Cathode material | Usage | Theoretical capacity (mAh/g) | Output | Energy density (Wh/kg) | Safety | Cost | Stable supply of raw material |
|---|---|---|---|---|---|---|---|---|
| Mg | Rock-salt type $MgNi_{0.8}Co_{0.2}O_2$ | Stationary | 470 | Under development | 1175 | ◎ | ◎ | ◎ |
| Mg | Spinel type $MgCo_2O_4$ | Stationary | 260* | Under development | 650 | ◎ | ◎ | ◎ |
| Li | Layered rock-salt type $LiCoO_2$ | Stationary, portable | 274 (140*) | ◎ | 530 | △ | × | △ |
| Li | Spinel type $LiMn_2O_4$ | Stationary, portable | 148 (110*) | ◎ | 440 | △ | ○ | ○ |
| Li | Layered rock-salt type $Li(Ni_{1/3}Co_{1/3}Mn_{1/3})O_2$ | Stationary, portable | 280 (200*) | ○ | 700 | △ | △ | △ |

* The spinel type has a theoretical capacity of 520 mAh/g when phase transition to the rock-salt type is taken into consideration.

**Points**

- High capacity and high energy density
- Low cost (free of rare metals)
- High safety

## Comparison with Conventional or Competitive Technologies

- The maximum cathode capacity of lithium-ion batteries (existing technology) per unit weight of cathode active material is 250 mAh/g.
- The cathode materials used in this technology already have sufficient potential as cathode materials for future secondary batteries. However, the electrolyte and anode material to be used in combination with these cathode materials have not been developed yet.

## Expected Applications

- Safe stationary storage battery
- Low-cost (free of rare metals) portable storage battery

## Challenges in Implementation

- Development of electrolyte with a high withstand voltage for detaching Mg in the rock-salt type
- Exploration of new compositions of spinel-type structures that can operate with a combination of high-capacity and high-cycle characteristics and establishment of ways to operate them for practical use

## What We Expect from Companies

We think this technology can be realized by researching material compositions that can reach the theoretical capacity.

We hope to conduct joint research with companies that have technology for synthesizing oxide ceramics.

It would be effective for companies that are developing electrolytes or have technology to produce advanced battery cells to adopt this technology.

## Future Developments

| | |
|---|---|
| April 2013 | Start of research |
| December 2014 | Successful development of spinel type |
| April 2015 | Successful development of rock-salt type |
| April 2016 | Production of prototype battery |

■ Associated System: JST Strategic Basic Research Programs Advanced Low Carbon Technology Research and Development Program
■ Intellectual Property: Japanese Unexamined Patent Application Publication No. 2016-164103 "Method for producing Magnesium composite oxides," Japanese Unexamined Patent Application Publication No. 2017-004770 "Positive electrode active material for Magnesium secondary battery, positive electrode for Magnesium secondary battery, and Magnesium secondary battery"
■ Sample: Available