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# Lithium secondary batteries in Japan

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**Abstract**

The Lithium Battery Energy Storage Technology Research Association (LIBES) conducts research and development on 'Dispersed Battery Energy Storage Technology' of the New Sun-Shine Program of the Agency of Industrial Science and Technology (AIST), Ministry of International Trade and Industry (MITI). This national project is being carried out based on the contract with New Energy and Industrial Technology Development Organization (NEDO). This R&D project for ten years with the budget of approximately Y14 billion has been started in the fiscal year 1992, and includes: (i) R&D of 20–30 kWh class high-performance ambient-temperature lithium secondary batteries, and (ii) study on the total system of lithium-battery application technology. This paper describes the project and current research activities.

*Keywords:* Secondary lithium batteries; Japan

## 1. Targets of the national project

The purpose of this national project is to develop a high performance ambient lithium rechargeable battery for load leveling. The targets are shown in Table 1.

Table 1
Targets of development

| | Long-life-type | High-energy-density-type |
|---|---|---|
| Mass energy density (Wh/kg) | 120 | 180 |
| Volumetric energy density (Wh/l) | 240 | 360 |
| Cycle life (cycle number) | 3500 | 500 |
| Energy efficiency (%) | ≥90 | ≥85 |
| Others | Securing of environment and safety, maintenance free | |

The capacity of lithium secondary batteries is assumed to be around 20 kWh for the long-life type and around 30 kWh for the high-energy type. The long-life type batteries will be applied to small-scale load-leveling systems for home use and the high-energy density type for electric vehicles.

The R&D project aims at the scale-up of cell energy capacity and assembled battery systems, and the improvement in performance such as enhancement of energy density and cycle life, based on the elemental studies and modular battery test module fabrication.

## 2. Milestone and budget

Milestone of this R&D project is shown in Table 2. The term for the research and development will be ten years, from the fiscal year (FY) 1992 to FY2001.

Interim evaluations are planned at the end of FY1995 and FY1998.

The total budget for this project will be approximately ¥14 billion.

R&D for ten years will be carried out efficiently by paralleling development and evaluation. The R&D term is devided into three phases:

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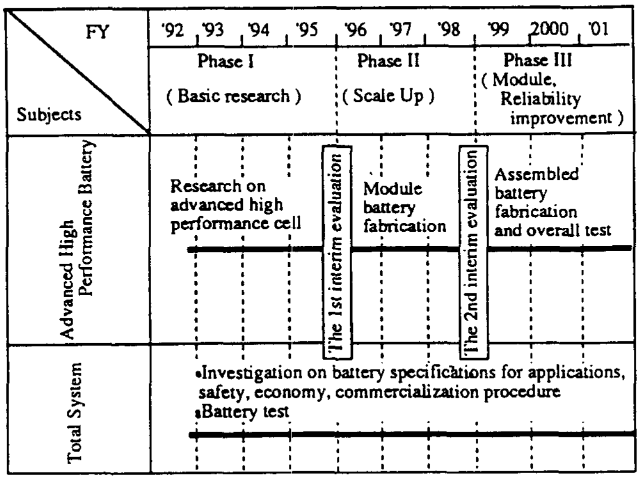
Table 2
Milestones: fiscal year




(i) phase I (FY1992 ~ 1995) for the R&D of elemental technology;

(ii) phase II (FY1996 ~ 1998) for the R&D of technology for cell capacity enlargement and assembling cells, and

(iii) phase III (FY1999 ~ 2001) for the R&D of commercializing level assembled battery which is made by combining large capacity cells in series or in parallel, and for confirmation of its performance by operation study. Cell units and assembled batteries to be developed in each phase are as follows:

(i) phase I: 10 Wh class cells;

(ii) phase II: 100 Wh class cell and several kWh class assembled batteries, and

(iii) phase III: 20–30 kWh class assembled batteries.

The final target will be achieved with the above-mentioned studies, and the measures for materialization and commercialization will be clarified.

## 3. Working structure

To conduct this R&D efficiently, Lithium Battery Energy Storage Technology Research Association (LIBES) has been established in January 1993. LIBES comprises ten companies and one institute, as shown in Fig. 1. LIBES allots the works of the R&D to each member based on the contract with NEDO; this work consists of research on high-performance advanced batteries and study on the total system.

The purpose of the LIBES activities is to conduct studies on battery electric energy storage technology with the cooperation of the organizing members, and to improve the technological knowledge of the members. LIBES is conducting an independent study on the newest technology of lithium secondary batteries to carry out the project properly and efficiently. The main parts of the independent study are:

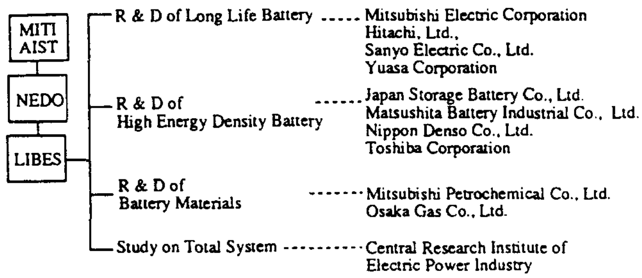



Fig. 1. Working structure.

(i) proposal of 'Society Vision in 21st Century', associating with high-performance batteries;

(ii) collection and analysis of information on lithium battery technology;

(iii) exchange of information on lithium battery technology, and

(iv) establishment of database concerning lithium secondary battery technology.

LIBES is planning to exchange the technological information with authorities, and commit to them the survey of technological projects in regard to R&D of lithium secondary batteries.

## 4. Current and future activities

The eight companies in charge of developing long-life lithium secondary batteries or high-energy density lithium secondary batteries are developing battery systems, as a combination of cathode material, anode and electrolyte materials, see Table 3.

In addition to the conventional cylindrical and square shapes, the stacking-type, whose electrode is contained in a folding structure, is suggested and the development of the three types are conducted parallely.

The two companies, material manufacturers of carbon materials or electrolytes, are conducting R&D of new materials based on the cooperative program with battery manufacturers under organic combination, as well as their original R&D based on their technological background.

As for the study on the total system, beside of big projects to clarify the measures for introducing the dispersed battery energy storage systems, it has the role to clarify the required items for batteries regarding the system and to give the technical guideline to the development of the battery. Therefore, it will make suggestions for the evaluation of the characteristics of battery development and give advises for the linkage to the system.

Main projects and the R&D of high-performance advanced batteries and the total system, which has been conducted during 1994, are mentioned below in Section 4.1.

Table 3
Features in R&D approach

| Battery systems | | | Features |
|---|---|---|---|
| Cathode | Electrolyte | Anode | |
| $LiCoO_2$ | Organic electrolyte | Carbon | Development of a new folding-type electrode structure using cobalt oxide of high potential voltage to prolonge cycle life and to obtain high-specific energy density |
| $LiMn_2O_4$ $LiNiO_2$ $LiCoO_2$ | | | Development of long-life battery by adopting graphite of superior quality concerning capacity and potential as the anode material |
| $LiMn_2O_4$ $(Li)V_xO_y$ | | Lithium–lead alloy | Prolongation of cycle life by adopting composite anode of Li–Pb alloys and carbon materials with superior cycle characteristics |
| $LiCoO_2$ | Solid polymer electrolyte | Carbon | Development of batteries with high reliability, safety, high shelf-life and long cycle life by using polymer electrolyte |
| $LiCoO_2$ | Organic electrolyte | Carbon | Improvement of the discharge capacity of cobalt oxide with high potential of suitable composition and structure, and improve of high performance by using carbon materials of long life as the anode materials |
| $LiNiO_2$ | | | Materialization of high-energy density by homogenization of the crystal structure of nickel oxide which has advantages for easiness to obtain resources, and by optimization of large-scale cell structure |
| $LiMn_2O_4$ | | Li–metal alloy + carbon | Improvement of the energy density by selecting lithium–metal alloy for high-potential and high-energy density, and in carbon compounds to improve cycle life and safety<br>As cathode materials, development of manganese oxide for reasons of resources and environmental issues |
| | | Li–metal | Improvement of the energy density of batteries by using cathode materials with controlled structure in nanometer order, and selecting lithium metal as the anode material in order to obtain high energy density |

### *4.1. Research on advanced high-performance battery*

#### *4.1.1. Investigation on cathode materials*

Research items for cathode materials are various lithium–metal oxides such as cobalt oxide, manganese oxide, nickel oxide and vanadium oxide.

The possibility to life elongation and capacity enlargement is being searched by replacing a part of those metal oxides with other transition metals, and investigating the effect of the replaced metal in a change in the crystal structure during charge/discharge cycles.

Moreover, studies on the degradation mechanism and methods to prevent this degradation will be conducted using vapour-deposited thin-film oxide materials controlling their composition and crystal structure.

#### *4.1.2. Investigation on anode materials*

##### *4.1.2.1. Carbon materials*

Effects of carbon-synthesizing methods and conditions, shapes, grain size are to be clarified in combination with various electrolytes in order to developing materials with high-capacity and long-life cycle.

The fundamental study on lithium absorption mechanism in carbon materials and interface-reaction mechanism has been started. The optimum crystal structure of carbon materials with discharge capacity beyond the theoretical energy density is investigated.

##### *4.1.2.2. Lithium metal*

The key technology for the lithium metal electrode is how to control the formation of dendrites. Therefore, the relationship between surface conditions and growth of lithium dendrites has been investigated, the effects of the electrode and electrolyte materials on the growth mechanism can be studied.

The dendrite growth on the anode which is composed of Li–metal alloy and carbon has been studied. Adequate carbon materials will be selected based on these results.

##### *4.1.2.3. Lithium alloys*

The effects of added elements to a lithium alloy has been studied in order to improve the discharge capacity and cycle life, and new lithium alloy electrodes will be developed. At the same time, the effects of the carbon materials–alloy compounds on the anode cycle life are to be investigated by changing the shape and size of the carbon and the composition of the mixture.

#### *4.1.3. Investigation on electrolytes*

##### *4.1.3.1. Liquid organic electrolyte*

By adding various solvents into the carbonate solvent, the characteristics of the conductivity and the potential stability are investigated, and the degradation mechanism is also investigated by analyzing the reaction products due to the electrolyte degradation. Based on these results, new electrolytes with improved performances will be developed.

##### *4.1.3.2. Solid polymer electrolyte*

The fundamental characteristics of solid polymer electrolytes are investigated and their degradation mechanisms are being studied. Based on the results, high-stable solid polymer electrolytes with improved characteristics may be developed. At the same time, the manufacture technology of thin-film electrolytes on the electrode is under development.

### *4.2. Study on the total system*

A study on the total system has been conducted to support the research and development of high-performance advanced batteries. For this purpose, multilateral and comprehensive studies on dispersed battery energy storage systems correspond with the R&D phases of high-performance advanced batteries. Feasible design, environmental conformity, safety, economy, procedure for commercialization are included in this study.

## 5. Results

The results of these studies are to be reported at NEDO's annual meeting and meetings in the field of battery development; information with authorities should be exchanged.

Papers of our studies have been reported at the following meetings:

(i) '93 Fall Meeting of the Electrochemical Society of Japan: qualification of the formation process of the cathode active material $LiCoO_2$ for lithium secondary batteries.

(ii) 61st Annual Meeting of the Electrochemical Society of Japan: design of lithium batteries for energy storage.

(iii) 34th Battery Symposium in Hiroshima, Japan: synthesis and electrochemical properties of $LiNiO_2$; synthesis of the cathode active material $Li_{1-x}M_xCoO_2$ (M = Na, K, Cu, Ag) for lithium secondary batteries; electrochemical stability of $LiPF_6$-based electrolyte solutions; study on the reaction mechanism of rechargeable lithium batteries, and influence on the electrode structure.

(iv) 7th International Meeting on Lithium Batteries, in Boston, USA: synthesis and properties of $LiNiO_2$ as a cathode material for lithium batteries; lithium/lead alloy composite anodes for lithium batteries, and charge/discharge characteristics of synthetic carbon anode materials for lithium secondary batteries.