Lithium-Ion Rechargeable Battery Technology Realizing High Safety and Long Life

SAITO Hideaki, KOJIMA Ikuo, OHTA Tomoyuki

Abstract

We at NEC Energy Devices, Ltd. develop and manufacture large-capacity lithium-ion batteries (LIBs) for use in electric vehicles (EVs) and large energy-storage devices. The LIBs of the NEC brand feature a manganese positive electrode with a laminated structure in order to achieve high safety and long life. We have established a mass-production method, achieving an annual electrode production capability of over two million kWh. At NEC Energy Devices, Ltd., we utilize our unique technology and mass-production capability to provide low-priced electrodes and batteries not only for EVs but also for drive power supplies and power supplies for energy storage as well.

Keywords

lithium-ion rechargeable batteries, manganese, laminated, large capacity
long life, safety, batteries for electric drive, power supply for energy storage

1. Introduction

Because the lithium-ion battery (LIB) has a high energy density, does not use environmentally restricted substances such as cadmium, lead, and mercury, and has a low energy loss during charge/discharge, it is considered environmentally friendly. It has been used in a wide range of applications; from compact mobile equipment such as mobile phones and digital cameras, to the power supply for driving motor-assisted bicycles and energy storage for uninterrupted power supplies (UPS). In recent years, the demands for increased scale and capacity of LIBs have been growing. This is due to the increase in interest regarding environmental issues such as global warming and to the needs for suitable countermeasures to deal with issues arising from large-scale disasters.

In December 2010, the Nissan Motor Company, Ltd. released "Leaf", a zero-emission electric vehicle (EV) that does not emit any CO_2 while driving. More than 20,000 Leaf vehicles are already on the roads worldwide. The electrodes at the heart of the battery mounted on the Leaf are the fruits of the technology of NEC Energy Devices. This paper introduces the features of the electrode and battery technologies designed to support the EV batteries and their applications for drive power supply and energy storage purposes.

2. Features Required for Battery Technology Supporting EV Batteries

Large batteries with large capacities such as EV batteries are required to implement high safety and long life at a low cost. A high safety factor is essential because an increase in the battery size leads to an increase in the stored energy and in the amount of electrolyte, which is flammable. As it is estimated that the users of EVs and large energy systems will use them for a long time after purchase, these products are required to offer long life and long-term reliability. In addition, although a larger battery requires a larger amount of materials, the products need to be affordable. Therefore, reduction in material cost and production cost is necessary.

To meet these requirements, we provide our batteries with two significant features: "manganese positive electrodes" and "laminated structure."

2.1 Manganese Positive Electrodes

We utilize lithium manganese oxide with a spinel structure as the active material of the positive electrode. The spinel does not change its crystalline structure according to the charge/discharge process, so it remains stable as a material even in an overcharged state (**Fig. 1**). In addition, the abundance of this material as a resource reduces issues related to procurement

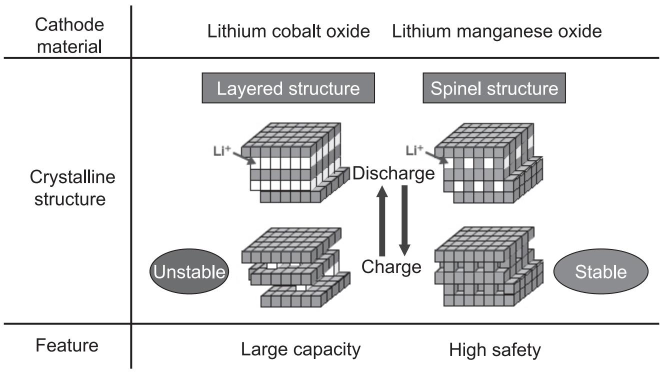

Fig. 1 Structures and features of the positive electrode materials.

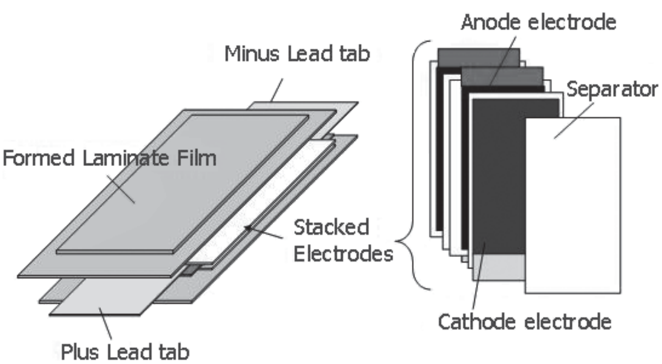

Fig. 2 Laminated architecture.

and enables cost reduction. However, the manganese positive electrodes of the past posed a problem because its life cycle performance was inadequate.

We ascertained that this resulted from the elution of the manganese due to the acid in the electrolytic solution. By mixing in lithium-nickel oxide as a proton scavenger, we succeeded in reducing the elution and improved the cell life significantly.

2.2 Laminated Architecture

Our LIB adopts an architecture in which power-generation elements consisting of multiple layers of electrodes are wrapped in aluminum laminate (**Fig. 2**). This replaces the traditional LIB architecture for mobile equipment batteries in which power-generation elements with a winded structure are mounted in an iron or aluminum can. The laminated structure can keep the resistance uniformly low and is also capable of a large-current discharge. Lowering the resistance leads to lowering heat generation, which then enables a battery that is thin, features first-rate heat radiation and is safe. Furthermore, laminating the electrodes enables a lighter battery with more flexibility in the shape of the design.

2.3 Establishment of the Mass-production Technology

We have succeeded in the mass-production of these electrodes and batteries based on the technology introduced above. The production line at the Sagamihara Research Laboratories has an annual electrode production capability of over two million kWh when converted into battery capacity. Meticulous care taken in the methodology, equipment, condition and environment that range from material procurement to fabrication enables a production with consistent quality.

3. Development of LIBs for Applications Other Than for the EVs

We are also developing innovative LIBs for applications other than EVs by making use of the high safety, long life and low cost of the EV-oriented LIBs.

One of the new LIBs targets energy storage applications. For the present, we are developing an energy storage LIB with a capacity of up to 32 Ah per cell (**Photo 1**). One of the key properties of the energy storage application is the long life, which can be implemented by applying the long life technology developed for the EV-oriented LIBs. The details of this device will be discussed in section 4 below.

Another new LIB is designed for the E-Bikes (Electric Bicycles). We are developing an LIB with a capacity of up to 15 Ah per cell (**Photo 2**). The demand for E-Bikes is high in China, Taiwan, and other Southeast Asian countries but most E-Bikes are based on lead-acid batteries because of their low prices and ready availability. However, due to the environmental effects of lead and the heaviness of lead-acid batteries, LIB is recently being adopted for its lightness and its low impact on the environment. Still, the demands in this market impose a difficult requirement, an impressively long life compared to lead batteries at a low price. Few battery manufacturers can meet these contradictory requirements. We respond to this challenge by offering the high safety, long life and low cost technology that we have developed with LIBs for EVs. We have led the market for power-assisted bicycles since the start

Photo 1 External view of the 32 Ah cell for the energy storage application.

Photo 2 External view of the 15 Ah cell for the E-Bike application.

of production in 2002. By using the know-how of the controls of motors and batteries acquired in this market, we plan to develop the E-Bike market.

4. Energy Storage Application

4.1 Needs of the Storage Battery

LIBs that have been commonly used for mobile phones and notebook PCs are now expanding its applications as large-capacity batteries for EVs. Moreover, since the Tohoku Earthquake of March 2011, the demands for energy storage systems based on large LIBs have been rising for uses as emergency power supplies and electricity storages for alleviating insufficiencies in the peak daytime electricity supply.

In the future, it is expected that renewable energy sourced by solar or wind generated power will be introduced in high volume. Since the generation of these energies cannot be controlled artificially, there is concern that the supply-demand balance in the power grid network could be lost. In order to utilize these systems with uncontrollable power generation, the use of large storage batteries of MWh class is being investigated.

4.2 Storage Performance Requirements

Table shows the performance requirements for the household energy storage systems that are being put to practical use and for the LIBs for EVs that have already been introduced. The household energy storage systems need to have a longer life of more than ten years compared to the energy storage system for EVs. Other than that, performance requirements are higher for the EVs. This means that many of the technologies for EV batteries can be applied to the household energy storage systems.

4.3 Development of Battery Packs for Home Energy Storage Systems

NEC commercialized a household energy storage system in July 2011. As shown in **Fig. 3** , this system is composed of a

Table Battery performance requirements for household energy storage system and EV.

Item	EV	Home System
Capacity	20 to 30 kWh	3 to 10 kWh
DC voltage	300 to 400 V	100 to 200 V
Rate	≤ 3 ItA	≤ 1 ItA
Service life	5 to10 years	10 to 15 years

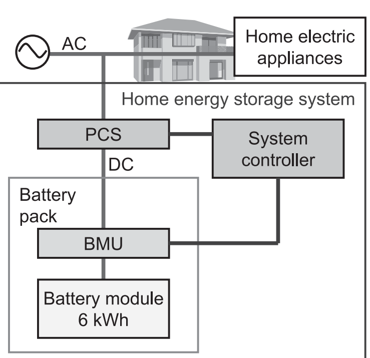

Fig. 3 Configuration of home energy storage system.

power conditioner system (PCS) that converts power from AC to DC to control the input/output power, a system controller that controls the system, and a battery pack. Of these components, NEC Energy Devices developed the battery pack.

The battery pack consists of a battery module combining multiple battery cells, and a battery management unit (BMU). The BMU includes a protection circuitry for monitoring for overcharge, over-discharge, over-current and temperature at all times as well as a circuitry for sending the remaining battery data and fault information to an external control system. This unit allows a battery pack to be incorporated in the system safely and easily.

5. Conclusion

We will continue to offer electrodes and batteries for drive power supplies and power supplies for energy storage as well as for EVs at low cost, taking advantage of our unique technology and mass-production capability. With regard to the power supplies for energy storage, we will further develop battery packs putting not only household use but also deployment of large energy-storage systems for commercial facilities, industrial facilities and power companies in perspective.

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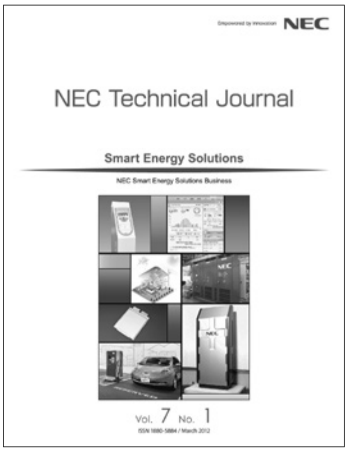

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