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Present status and future prospect for national project on lithium batteries

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Abstract

Sales of lithium-ion battery in Japan increased so sharply since the battery was on sale in 1992. ‘Dispersed-type Battery Energy Storage Technology’ of New Sunshine (AIST) program have stimulated R&D of lithium batteries in Japan. In this project on lithium batteries, Osaka National Research Institute (ONRI) plays a main role by coordinating the project from a neutral standpoint and supporting it with a basic research for battery material. A research background for electrochemical devices and research activity in the field of lithium battery at ONRI are introduced. Then, future prospect of a role of battery in a society in the next century is described regarding to an ‘environment’ and ‘human being’.

Keywords: Lithium-ion battery; Energy storage; Electrochemical

1. Introduction

A remarkable trend in Japan which has taken place in these 2 years is the dramatic widespread use of cellular phones. At the end of April 1998, registered cellular phones in Japan exceeded 33 million. This amounts to one cellular phone for every four Japanese. What is especially worth-mentioning regarding cellular phones is that the loading ratio for lithium-ion batteries is almost 100% in Japan. In other words, 25% of all Japanese people carry Li-ion batteries every day.

Sales of Li-ion batteries have increased sharply since 1992, as shown in Fig. 1 [1]. At present, although the production number of nickel–metal hydride batteries is still larger, sales of lithium-ion batteries overcame nickel–cadmium and nickel–metal hydride batteries in 1995. Now, except for lead–acid batteries, lithium-ion battery sales account for no less than 50% of the total sales of secondary batteries. The production number of lithium-ion batteries in 1997 corresponds to a purchase of more than one battery for each citizen.

Lithium-ion battery usage is gradually spreading to large-scale battery systems, like power sources for electric vehicles and energy storage for load leveling. Electric vehicles, fuel cell vehicles, and hybrid vehicles with advanced batteries were among the first in the world to be manufactured and sold in Japan. We even see some of them running downtown. We can see an electric vehicle loading lithium-ion battery like ALTRA EV manufactured by Nissan Motor Co. [2]. This vehicle is put to lease.

The battery technology of Japan can be said to be one of the most advanced in the world. At present, we are developing a large-scale lithium battery system for electric vehicles and energy storage. ‘Dispersed-type Battery Energy Storage Technology’ in the NSS (New Sunshine) program of the Japanese government, which started in FY1992, has been stimulating R&D on large-scale battery systems in Japan. This is one of the biggest and most challenging programs in the NSS.

In this paper, the history of the National program in the energy storage field and the present status of the present program are explained, focusing on the role of the ONRI (Osaka National Research Institute), and then, what the battery will be in the near future is described.

2. The history of ONRI in R&D on battery systems

Fig. 2 shows a ‘flow’ of research on electrochemical devices over 20 years. Our institute has played an important role in these projects with the ‘potential’ to research

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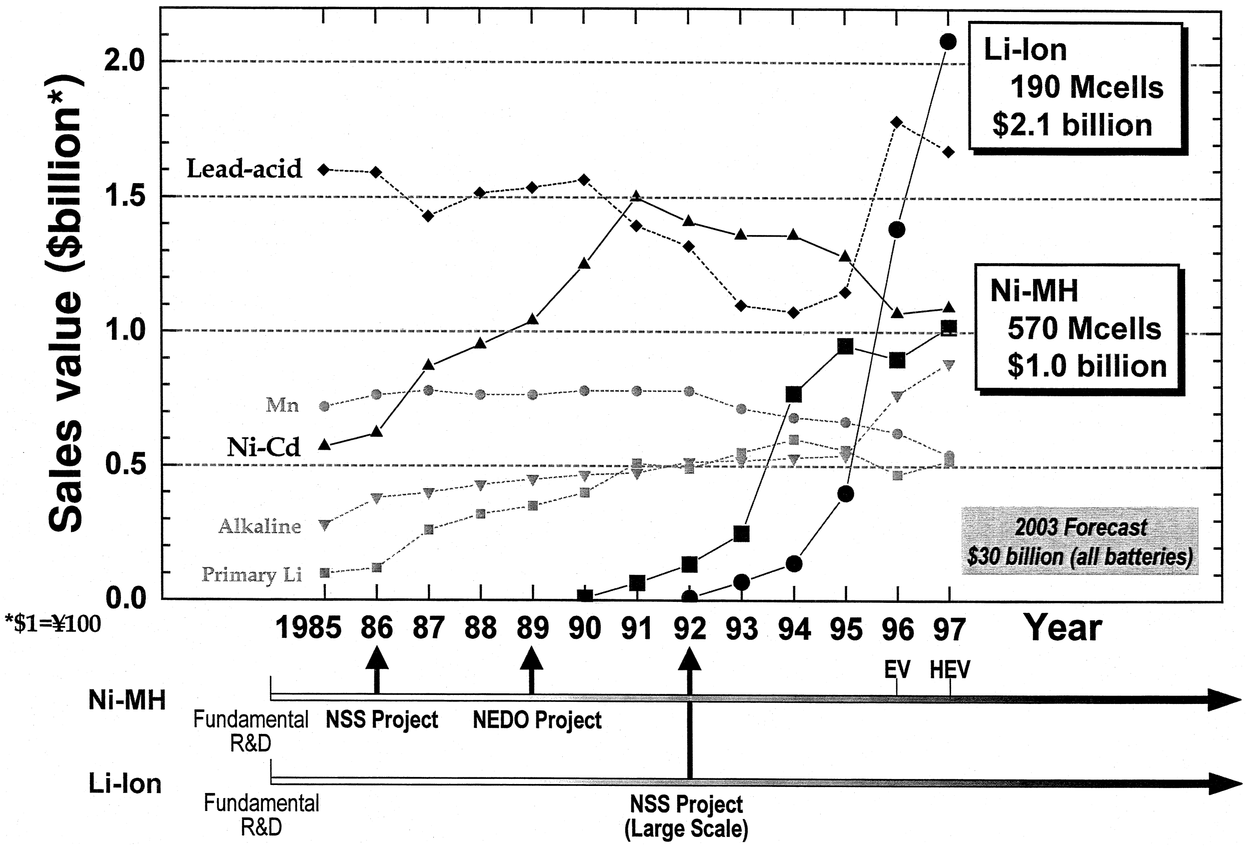

Fig. 1. A statistics of sales in the market of several kinds of batteries.

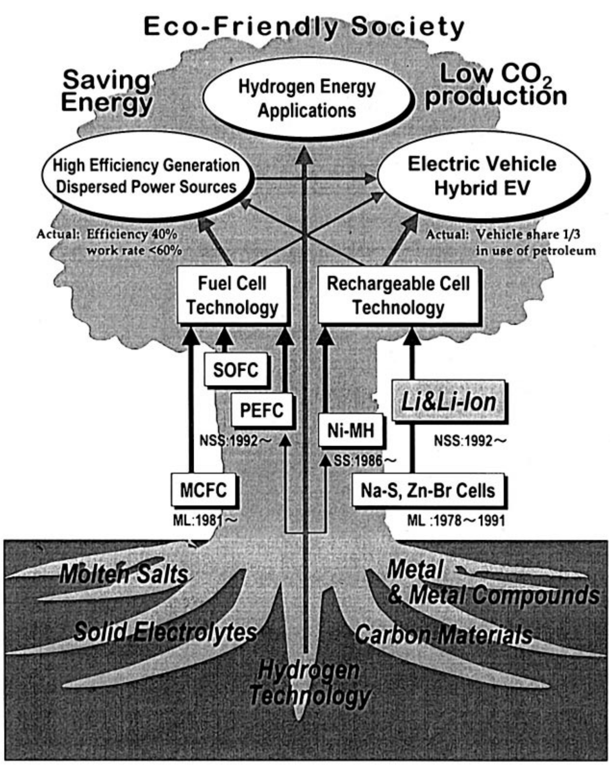

Fig. 2. Research programs on electrochemical devices at ONRI.

new materials. In this decade, we have two conflicting goals: one, is an increasing demand for energy and the other is maintenance of the environment. We became conscious of the importance of a system in which these two goals could be satisfied at the same time.

At present, large parts of manpower and budgets are concentrated on batteries, especially lithium batteries. History of battery research is noted briefly as a background of research on lithium batteries. Fifty years ago in 1948, we began a study on mercury oxide batteries. Since then we have continued to investigate the basic technology of several kinds of batteries focusing on secondary batteries as a national project and at the same time, we organized various programs including EV (electric vehicle) battery technology, in which the basic technology for advanced electrochemical systems originated (Fig. 3). As an example of EV research, we could introduce a hybrid vehicle with hydrazine–air fuel cell and lead–acid battery (Fig. 4). This hybrid car was manufactured and a fleet test was carried out in our institute in a research program from 1968. We are proud of this vehicle as a pioneer ‘ecological vehicle’. Particularly from 1971, research on batteries for electric vehicles started as a large-scale project. In this project, more than five kinds of batteries, as shown in Table 1, were developed and the possibility for their practical use was explored. The technology that originated from this

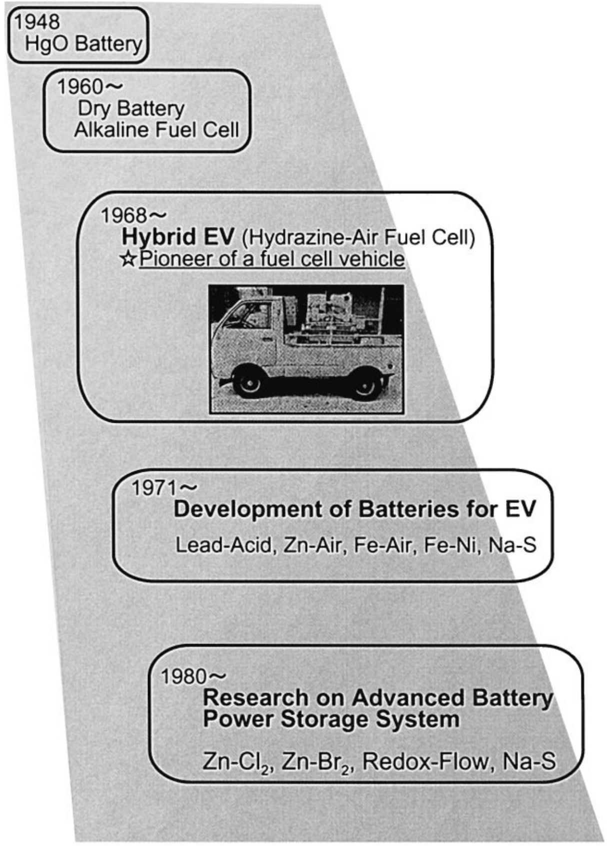

Fig. 3. Research programs in the past in battery field at ONRI.

program resulted in the establishment of some basic technology that has contributed to today's battery technology. In our institute, the potential for study on batteries like this and potential for materials research (oxides, carbon materials, metal hydrides, etc.) lead to today's research program. In succession to it, aiming at energy conservation, 'Research on Advanced Battery Power Storage System' (FY1980–FY1991) was carried out focusing on $Zn–Cl_2$, $Zn–Br_2$, Na–S, and redox-flow battery. As a result of

Table 1
Goals and tested results of batteries in the research program 'Development of Batteries for EV'

	Energy density (W h/kg)	
	Target	Result
Lead–acid	30–50	40 (0.3 C)
Zn–air	Over 80	
(Stationary)		85.5 (0.3 C)
(Circular)		72.5 (0.3 C)
Fe–air	Over 70	40 (0.3 C)
Fe–Ni	60	82.5 (0.2 C)
Na–S	85	90.5 (0.2 C)

implementation of such large-scale projects on power storage system for more than 10 years, we have come to recognize the necessity of advanced batteries with higher-energy density for realization of more successful systems for electric vehicles and power storage. At the moment this program was finished, research on nickel–metal hydride batteries, which was more promising among advanced batteries, has been carried out from the 1980s. Nothing other than the lithium battery, that could surpass the energy density of the nickel–metal hydride battery, could be found (Fig. 5). In those days, the lithium battery was thought to have safety difficulties, however, safety problems were about to be solved by the application of the carbon anode. Then it has just exceeded the level of 'unuseful battery'. We believe it is our mission to scale-up the lithium battery while simultaneously improving safety, which was still difficult in private companies at that time. Our institute plays an important role in the coordination of the latest programs on several electrochemical device, and of course, leading the research on lithium batteries mainly in 'Dispersed-type Battery Energy Storage Technology', which aims at battery scale-up. Our research activity for the lithium battery including 'Dispersed-type' project is introduced hereafter.

Fig. 4. Hybrid vehicle manufactured in a research program from 1968.

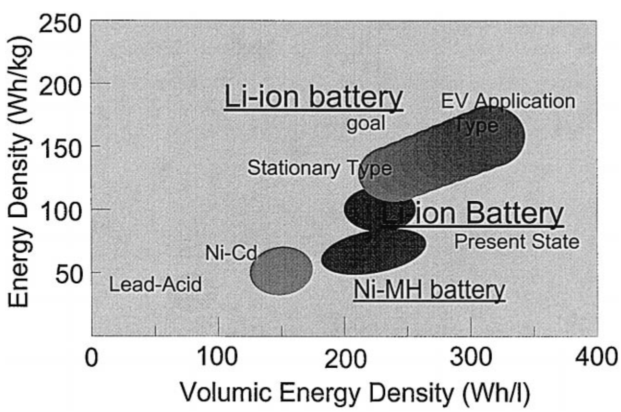

Fig. 5. Energy density of secondary batteries (large-scale cell or module level).

3. R&D for lithium batteries involving 'Dispersed-type Battery Energy Storage Technology' project at Osaka National Research Institute

Research organization of this project, which involves 11 major companies and three national institutes in Japan, is shown in Fig. 6. These companies which actually manufacture batteries or provide battery material are organized as LIBES (Lithium Battery Energy Storage Technology Research Association). LIBES is entrusted by NEDO (New Energy and Industrial Technology Development Organization) for R&D and evaluation of batteries. The current status of battery manufacturers in detail is not discussed here. Our research activities are mainly introduced here. The National institute is responsible for improvement of present problems and development of next generation batteries by creating new material and elucidating mechanisms of electrode material.

Osaka National Research Institute plays two main roles; one is a coordination of research. From a neutral standpoint as a government agency, we are concerned with management of a society of research groups supporting the project. It provides a place for exchanging information or opinions to researchers in the battery field. The other, that is more essential, is actual research (Fig. 7). A figure of the battery that we aim at is a 'practical', 'next generation' battery in the case of scaling up. For this goal, we synthesized new materials and investigated the mechanism of electrode material involved in electrochemical reaction [3–25]. And then, we can continue to realize more reliable batteries. In this case, we make much of difficult subjects that are sometimes troublesome for private companies because of a necessity of rather long research periods. Briefly, two examples are refereed; one example is an iron cathode material. We have investigated the possibility of using iron compounds as a cathode in order to reduce the cost of a battery [3–6,10,11]. The second example is a lithium metal anode. After all, it should be an essential solution for improvement of the energy density of batteries. However, the prospects of it are still far from certain even at present with some small breakthroughs resulting from more than 40 years of research [26].

In addition to these future technologies, we have continued to investigate mechanisms of electrochemical reaction of the materials that have already reached production level, such as carbon anode [17–21], for the purpose of improvement in both performance and safety.

4. Future prospects for the national project

As stated at the beginning of this article, the lithium battery project has intensively stimulated and accelerated

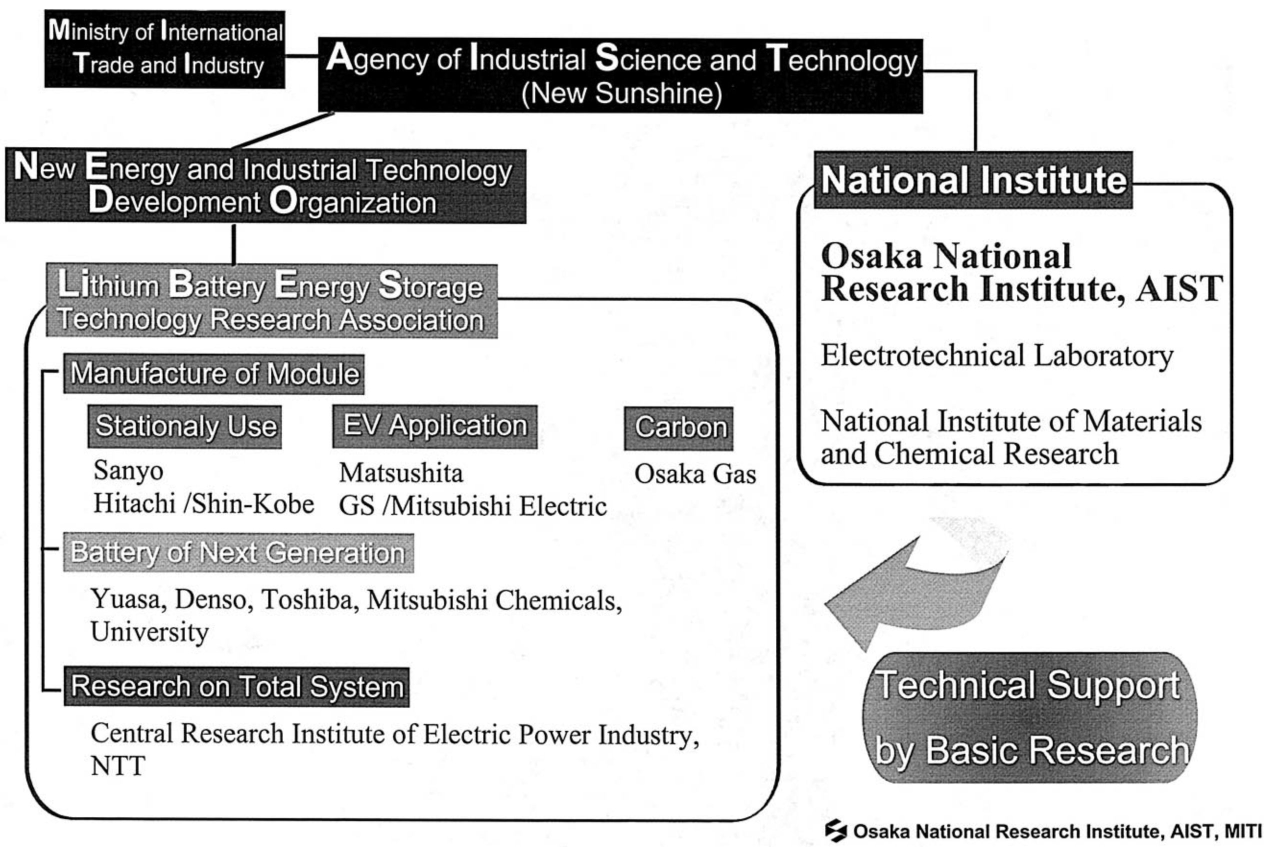

Fig. 6. Research organization of 'Dispersed-type Battery Energy Storage Technology' project.

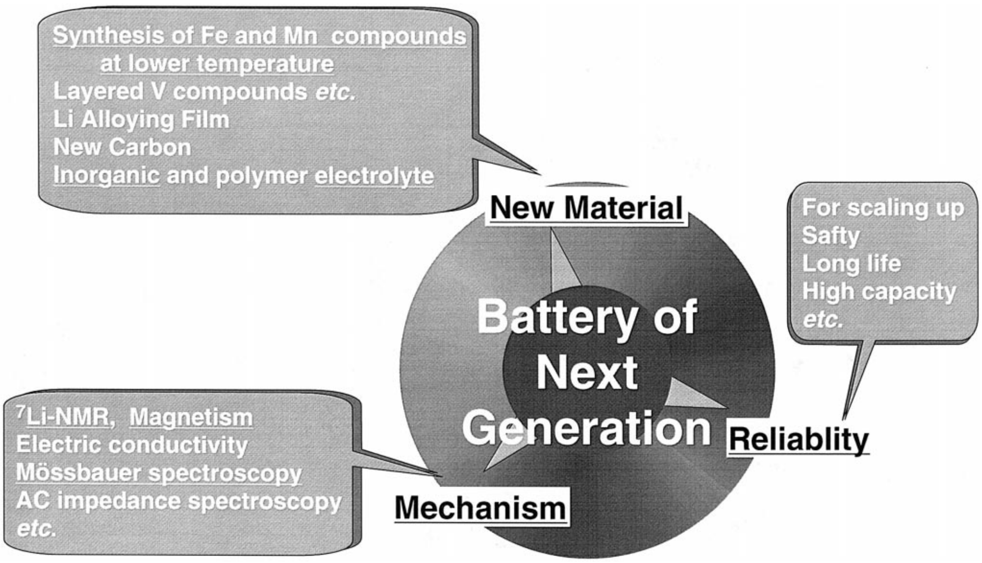

Fig. 7. Research activity on lithium batteries at ONRI.

R&D and commercialization for a market of a power sources for portable electric devices. Of course, this marvelous growth is the result of a great and untiring effort of all companies involved in the lithium battery field. However, attention should be paid to the year corresponding to the onset of sales of nickel–metal hydride and lithium-ion batteries as shown in Fig. 1. This coincides with the beginning of projects involving ONRI. In general, considerably long periods are necessary for planning processes of large-scale projects like this. We have continued to provide ‘a cue’ for a new generation battery to enter into the market and then to increase its commercial importance. As was already commented, in the 80 years since the Osaka National Research Institute was founded, we have always been contributing to create a new industry by starting ‘something new’ and stimulating a certain market. At the present stage, some projects for the development of basic technology of a new kind of battery are about to start in parallel with ‘Dispersed-type Battery Energy Storage Technology’, in preparation for the next large-scale project. Entry of a new kind of battery in the market in the near future could be expected.

An industrial society has been developing in which ‘environment’ and ‘human existence’ which should be keywords have actually been given little consideration. Regarding ‘environment’, it has been shown that a policy for energy development should not ‘stand alone’ and that the policy has to be eco-friendly; or play an active role to maintain our environment. Batteries can be said to be a ‘key device’ for realization of these energy policy attitudes. It is not too much to say that the success of the ideal society or system depends on battery performance. A typical example of this is an electric vehicle. The lithium battery makes the EV practical by sufficiently extending its navigable distance.

‘Human existence’ is an important keyword for our institute, which is deeply concerned with the ‘environment’. Construction of a new society, free from the present industrial society, in which science and technology for better human life is essentially important, will be necessary in the next century. In such a society, that is, a high-level welfare society maintaining a high-level environment, electrochemical devices will play a leading role and that we can achieve no benefits without high-performance battery systems. Then, how will the society be embodied? We, along with our institute, have been looking for its solution in our own way.

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References

[1] Statistics from ‘Battery Industrial Association’, for example, http://www.hi-ho.ne.jp/batteryjapan/totalstat1002.htm.
[2] K. Suzuki, Proceedings of 14th International Symposium on Electric Vehicle, 2A Electric Vehicles, 1997.
[3] H. Sakaebe, S. Higuchi, K. Kanamura, H. Fujimoto, Z. Takehara, J. Electrochem. Soc. 142 (1995) 360–365.
[4] H. Sakaebe, S. Higuchi, K. Kanamura, H. Fujimoto, Z. Takehara, J. Power Sources 56 (1995) 165–169.
[5] H. Sakaebe, S. Higuchi, K. Kanamura, H. Fujimoto, Z. Takehara, Solid State Ionics 79 (1995) 234–238.
[6] K. Ado, M. Tabuchi, H. Kobayashi, H. Kageyama, O. Nakamura, Y. Inaba, R. Kanno, M. Takagi, Y. Takeda, J. Electrochem. Soc. 144 (1997) L177.

[7] M. Tabuchi, K. Ado, H. Kobayashi, H. Kageyama, C. Masquelier, A. Kondo, R. Kanno, J. Electrochem. Soc. 145 (1998) L49.
[8] C. Masquelier, M. Tabuchi, K. Ado, R. Kanno, Y. Kobayashi, Y. Maki, O. Nakamura, J.B. Goodenough, J. Solid State Chem. 123 (1996) 255.
[9] M. Tabuchi, K. Ado, C. Masquelier, I. Matsubara, H. Sakaebe, H. Kageyama, H. Kobayashi, R. Kanno, O. Nakamura, Solid State Ionics 89 (1996) 53.
[10] M. Tabuchi, C. Masquelier, T. Takeuchi, K. Ado, I. Matsubara, T. Shirane, R. Kanno, S. Tsutsui, S. Nasu, H. Sakaebe, O. Nakamura, Solid State Ionics 90 (1996) 129.
[11] M. Tabuchi, K. Ado, H. Sakaebe, C. Masquelier, H. Kageyama, O. Nakamura, Solid State Ionics 79 (1995) 220.
[12] M. Tabuchi, C. Masquelier, H. Kobayashi, R. Kanno, Y. Kobayashi, T. Akai, Y. Maki, H. Kageyama, O. Nakamura, J. Power Sources 68 (1997) 623.
[13] M. Shikano, H. Sakaebe, N. Wakabayashi, S. Higuchi, Solid State Ionics 108 (1998) 327–332.
[14] H. Kobayashi, R. Kanno, Y. Kawamoto, M. Tabuchi, O. Nakamura, M. Takano, Solid State Ionics 82 (1995) 25.
[15] H. Kobayashi, R. Kanno, Y. Kawamoto, M. Tabuchi, O. Nakamura, Solid State Ionics 86–88 (1996) 859.
[16] H. Kobayashi, R. Kanno, M. Tabuchi, H. Kageyama, O. Nakamura, M. Takano, J. Power Sources 68 (1997) 686.
[17] K. Tatsumi, T. Kawamura, S. Higuchi, T. Hosotubo, H. Nakajima, Y. Sawada, J. Power Sources 68 (1997) 263.
[18] K. Tatsumi, J. Conard, M. Nakahara, S. Menu, P. Lauginie, Y. Sawada, Z. Ogumi, Chem. Commun. (1997), p. 687.
[19] K. Tatsumi, T. Akai, T. Imamura, K. Zaghib, N. Iwashita, S. Higuchi, Y. Sawada, J. Electrochem. Soc. 143 (1996) 1923.
[20] K. Tatsumi, K. Zaghib, Y. Sawada, H. Abe, T. Ohsaki, J. Electrochem. Soc. 142 (1995) 1090.
[21] K. Tatsumi, N. Iwashita, H. Sakaebe, H. Shioyama, S. Higuchi, A. Mabuchi, H. Fujimoto, J. Electrochem. Soc. 142 (1995) 716.
[22] S. Koike, T. Fujieda, N. Wakabayashi, S. Higuchi, J. Power Sources 68 (1997) 480.
[23] T. Takeuchi, K. Ado, Y. Saito, M. Tabuchi, H. Okuyama, O. Nakamura, Solid State Ionics 86–88 (1996) 565.
[24] T. Takeuchi, M. Tabuchi, K. Ado, K. Honjo, Y. Suyama, N. Ohtori, M. Nagasawa, O. Nakamura, H. Kageyama, J. Mater. Sci. 32 (1997) 4053.
[25] T. Fujieda, N. Yamamoto, K. Saito, T. Ishibashi, M. Honjo, S. Koike, N. Wakabayashi, S. Higuchi, J. Power Sources 52 (1994) 197.
[26] K. Kanamura, S. Shiraishi, Z. Takehara, J. Electrochem. Soc. 141 (1994) L108.