Vergleich der Strategien und Aktivitäten in Deutschland und Japan auf dem Gebiet der Lithium-Ionen-Batterie Forschung

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Abstract

Die Batterie-Technologie stellt eine Schlüsseltechnologie zukünftiger, regenerativer Energieversorgung dar. Regenerative Energien auf Basis von Sonne- oder Windkraft sind starken Schwankungen unterworfen. Daher wird ein Energiespeichersystem benötigt, das in der Lage ist Überkapazitäten zu speichern und im Bedarfsfall wieder abzugeben. Batterie-Systeme ziehen viele Forscher an, weil die Kombination aus regenerativer Energiegewinnung mit Batterie-Systemen, die beste Antwort für ein nachhaltiges Energiesystem ist. Die Batterie-Technologie könnte das „Petroleum" des 21. Jahrhunderts werden und so für eine nachhaltigere Entwicklung der Gesellschaft sorgen. Gegenwärtig sind vor allem asiatische Länder wie Japan, China und Südkorea führend bei der Entwicklung von Lithium-Ionen Batterien. Um den Rückstand gegenüber Asien aufzuholen und eines der führenden Länder im Bereich der Batterieforschung und -entwicklung zu werden, wurden von der deutschen Bundesregierung und von Seiten der Industrie verschiedene Projekte zur Erforschung der Lithium-Ionen-Batterie initiiert. Insbesondere das LIB2015 Projekt ist derzeit weltweit eines der größten Batterieprojekte, das Themenbereiche von der Grundlagenforschung bis hin zur Anwendung abdeckt. Darüber hinaus versucht sich die Firma Li-Tec Battery GmbH, ein Joint Venture von Daimler und Evonik am Markt mit "Batteries made in Germany" zu etablieren. In Japan hat jedoch bereits die Forschung an neuen Batteriesystemen begonnen, mit dem Ziel verbesserte Energiespeicher für die nächste Generation von Lithium-Ionen-Batterien zu entwickeln. In diesem Beitrag sollen aktuelle Batterieprojekte in Deutschland und Japan verglichen werden: Wie ist die Struktur der Organisationen und welche Ziele werden verfolgt. Darüber hinaus sollen die Zukunftsperspektiven der Batterie-Forschung sowie die Kooperationsmöglichkeiten anderer Länder mit Deutschland dargestellt werden. Schließlich sollen wirtschaftliche Aspekte und die Frage, ob die Batterie-Technologie als Wachstumsmotor für mehr Beschäftigung in Deutschland und Japan sorgen kann, diskutiert werden.

Introduction

Battery technology is attracting a lot of interest because batteries will be the key device for sustainable energy systems based on renewable energy.[1,2] An especially strong need exists for batteries, which can repeat storage and supply a large amount of electrical energy in a small volume in a short time, i.e. batteries with high energy density and high power density. A Li-ion battery (LIB) system has both a high energy density and high power. From this point of view, LIBs are serious candidates for an energy storage device, which is expected to be combined with renewable energies, such as solar power and wind power. Therefore, intensive research for batteries is under way under highly competitive conditions.

In this paper, the Japanese and the German strategies for battery research are compared. We will deal with (1) clarifying the current status of battery research for each country, (2) discussing the strategy for current battery projects, and (3) elucidating the possibility for the creation of new jobs in Germany and/or Japan and the strategy for the cooperation with other countries.

Again, Why Batteries?

Why are batteries one of the hottest topics in the research fields from fundamental to industrial sciences, especially in the European Union (EU), Japan, South Korea, China, and in the United States of America (USA).

There are three main reasons for such intensive researches on batteries: (1) energy problems, (2) climate changes, and (3) economic reasons. The reasons (1) and (2) are strongly linked. Since the industrial revolution in the 18th century in the western world, and current big economic growth in the eastern world, cheap energy sources, such as coal and petroleum, are the key element for the improvement of quality of life (QOL) resulting from industrial improvement.[3,4] However, cheap energy depends on fossil fuels generating a huge amount of carbon dioxide (CO_2). The discussion about the relationship between climate change and CO_2 is still continuing, however, CO_2 is

suspected as the main reason of climate change.[4] Also, these energy sources are limited. Here we find the biggest challenge: How to keep our QOL while keeping on developing our society with less "last century's fuels." For this challenge, we should consider the expected enrollment for our society, industry, and science.[5]

Firstly, we will decide to use sustainable energies. One of the most ambitious projects for creating electrical energy and grid from photovoltaic, the DESERTEC project, predicts that the ratio of solar power and wind power to oil, gas, and coal in EUMENA (EU, Middle East, and North Africa) will be 1 to 1 in 2050.[6] The concrete ratio for the content of energy source for the next 50 years could make a lot of discussions, however, this project suggests that we will use more sustainable energy than current utilization of it. This means that solar power and wind power plants will be used as large and/or local scale power stations. They will supply electrical energy as a backbone of a power network. But a serious problem of solar and wind power is instability of energy supply. They depend completely on natural conditions. So people start to look for rechargeable (or secondly) batteries.[7] This paradigm shift on energy leads the change of the economic trend (3).[8] The rechargeable battery system, one of the most promising device for integrating into a grid system depending on a renewable energy, changes enterprises' plans, especially those of car companies.[9]

German and Japanese Motivation on Battery Research

Table 1 and Table 2 show the world share of LIBs for consumer use and patents for LIBs, respectively. [2,10]

Table 1: The world share of LIBs for consumer use in 2009 and 2010[10]

	2009		2010	
Place	Company	Share	Company	Share
1	Sanyo	19%	Samsung SDI	21%
2	Samsung SDI	18%	Sanyo	20%
3	SONY	13%	LG Chem	17%
4	LG Chem	12%	SONY	12%
5	BYD	7.4%	Panasonic	6.3%

Table 2. The world share of patents for LIBs.[2]

	2000–2004		2004–2008	
Place	Nation	Share	Nation	Share
1	Japan	57.5%	Japan	35.4%
2	USA	15.8%	USA	16.8%
3	South Korea	9.7%	South Korea	16.6%
4	Germany	4.8%	China	6.2%
5	China	3.8%	Germany	4.8%

The tables show that the main companies for LIBs production are Asian (Samsung SDI is Korean, Sanyo is Japanese, and BYD is Chinese). If we summarize the share of LIBs' production in 2010 from first to tenth place, Asian companies occupied about 87% of the world's production.[10] In case of patents, Asian-originated companies and institutions hold about 60% of the total number of patents for the technology for LIBs.[2] These statistics suggest a hegemonic distribution of battery technologies in Asia like for petroleum in the Middle East. As we discussed before, LIBs are expected to be a key part of a grid system, which depends on sustainable energy systems.[7,9,10] From these backgrounds, countries such as Germany, Japan, France, and the USA, want to create their own battery projects and initiate a new industry.[11]

According to information of the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF), there are three main goals for the German federal battery project (Bundesländer Projekt)[11]: "Langfristige Sicherung von Mobilität in Deutschland über die Elektromobilität mittels innovativer Batterietechnologien", "Qualitätssiegel (Made in Germany)", and "Schaffung neuer Arbeitsplätze." This means that Germany wants to have battery technologies for (1) sustainable mobility, (2) battery market, and (3) creation of new employment. There are several weak points in Germany for battery researches. BMBF mentioned as one of the most important that "there is no major German cell or battery maker." But in Germany there is a strong research ability for fundamental science and the strong industry.[12a] From this condition, the German initial motivation for battery research can be described as starting from a comprehensive research on the LIB systems for cars with the support of government and states, especially, on electrochemistry, materials, production process, and recycling.[12b]

Japan is carrying out continuous and intensive research on rechargeable batteries. The national project has started as early as 1992, (LIBES project, 1992–2001).[13a] Japan has already major battery companies and major research institutes for the whole field of battery materials.[13b] The Japanese motivation for battery research is improvement of LIB system and creation of new battery systems for electronic vehicles (EVs), especially to overcome the limitation of fossil fuels and the climate change.[13c,d]

German Strategy for Battery Research

As we already mentioned, Germany wants to have battery technology from fundamental to industrial field. Therefore, German projects have various structures. "Lithium Ionen Batterie LIB 2015" is one of the biggest battery projects in the world. This is an all Germany project.[14] Münster Electrochemical Energy Technology (MEET) is a project of one state (Nordrhein-Westfalen), conducted by Prof. Martin Winter at the University of Münster.[15] EnerChem project is a research alliance initiated by five Max-Planck-Institutes (MPIs).[16] BASF started a new academic R&D network.[17] Additionally, Daimler AG and Evonik Industries AG founded a Li-Tec Battery GmbH, a joint venture for battery production.[18] Here we can find a variety of German research activities from fundamental science (MPIs) to industry (Li-Tec) – Germany is trying to get in touch with comprehensive and improved LIB technologies. Moreover, we can find several projects conducted by local states. Of course, most projects receive their budgets from the central government (or an organization closely connected). However, independence of research seems to be higher than in Japan. Some German battery projects are decentralized and that decentralization is one reason for the variety of German research.

Japanese Strategy for Battery Research

Japanese battery projects are mainly conducted by the central government or related organizations, for example through the New Energy and Industrial Technology Development (NEDO).[19] The

reason for the centralized structure is that the energy problem is one of the most serious issues for Japan (see the Energy Crisis at 1970's). Therefore, the Japanese government needs to focus on energy technologies and enhancement of the related industrial competitiveness.[20] As already shown in this paper, Japanese battery projects are focusing on batteries for cars.[13c,d] There are two major running projects. One is the R&D Initiative for Scientific Innovation of New Generation Batteries (in short, RISING project).[21] The RISING project (a NEDO project, planned for 2010–2015) is conducted by Prof. Zenpachi Ogumi (Kyoto University). The main institutions concerned are Kyoto University, TOYOTA Motors, and the National Institute of Advanced Industrial Science and Technology (AIST). The focal points are "development of advanced analysis techniques," "analysis of battery reaction," "materials innovation," and "development of new generation batteries." This project aims for improvement of LIB systems and the development of post-LIB systems by using the results of improved LIB systems.

The other project is Innovative Basic Research Toward Creation of High-Performance Battery (project leader is Prof. Noritaka Mizuno of Tokyo University).[22] The mission is (1) rational materials design on the atomic and molecular level, (2) developing new-concept storage batteries, (3) developing high level analysis and interpretation technologies, and (4) developing material computation and simulation technologies.[23] The main institutions concerned are Tokyo University, TOYOTA Motors, and AIST.

We find that the final goal of these two projects are post-LIB systems. This is because the current LIB system are already predicted to reach their maximum property.[13e,24] The prediction tells us that we can achieve the best LIB in 2020. And its property is ca. 200 km/charge for an EV (assuming 80 kg of batteries, 20 kWh). This property is too low compared to current cars with combustion engines. From this point of view, the Japanese projects focus on post-LIB systems, for example, all-solid-state-batteries, lithium-sulfur batteries, and lithium-air batteries.[13f,21,22] Germany is also carrying out research for these systems.[17,25] However, it seems that the Japanese projects are more focusing on post-LIBs. For more about post-LIB systems, see reference 26.

Summary of Current German and Japanese Battery Research

Here, we briefly summarize the German and Japanese current battery research (Table 3).

Table 3. Short Summary of German and Japanese Battery Research

	Germany	Japan
Battery	LIBs	Post-LIBs
Target	Mobility	Mobility
Structure	Decentralization	Centralization

The main target is initiating the mobility based on EVs (containing plug-in hybrid vehicles). Also, both countries are aiming to have some part of the future battery market and create new jobs.

International Collaboration Research and Possibility for Creation of Employment

Let us have a look on Germany first. In the EU, there is one battery project, Advanced Lithium Energy Storage Systems European Research Institute (ALISTORE-ERI, from 2008).[27] Almost all main European battery research institutes join in this project, for example, CNRS, La Sapienza University, St.-Andrews University, Uppsala University. However, no German institute joins in this European project. France has rich experience for research on rechargeable batteries. From this point of view, it could attractive if Germany and France would join in battery research projects. However, as we know already, there is an interesting international research project initiated by BASF.[17]

Japan has no practical international project for batteries yet but is looking for possible cooperation, especially with USA, France, and Germany. However, as shown in Tables 1 and 2, the center of current battery research and production is Asia. From this point of view, it could be the most active alliance in the world if Japan, South Korea, and China decide to cooperate in this field.

How about creation of new jobs? The main challenge for the job

creation in Germany and Japan is high labor cost that makes it difficult for them to compete in mass production of cheap batteries. If they want to create a big number of jobs in their countries by battery productions, this battery must have superior properties, so one can sell this battery with high cost but high quality. In this case one can manage the labor cost. To protect the superiority of battery properties, the control of technologies could be also serious issue. In 2008, for Li-ion batteries cost was about 2000 $/kWh. However, in 2011, LG Chem presented 400 $/kWh batteries at the Hybrid Vehicle Technologies Symposium. This means that the highly competitive cost competition already started in the current LIB market.

Therefore, LIBs of the next generation and post-LIBs in Germany and/or Japan should be difficult to copy their technology. And also, there should be a way to sell batteries made in Germany (or Japan) at emerging markets in Asia.

Finally, let us discuss the German chances in battery research. Li-Air battery systems, one of the most promising post-LIB systems, is similar to fuel cells. Germany has rich experience in fuel cells. There is a strong will of German citizens, politics, and scientists for renewable energies.[5,28] If you remember the Apollo project in USA (1960s and 70s), we can find that the great triumph resulting from the strong acceleration of technology against a difficult challenge can be achieved when citizens and leaders have the same dream. German citizens, politicians, and scientists seem to be unified in promoting renewable energy. So the country has a big chance to become a leading country on battery technology in the next 20 years.

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