CHINA'S NA-ION BATTERY INDUSTRY RUSHING TO MASS PRODUCTION STAGE

— MAKING PREEMPTIVE MOVES TO GAIN THE UPPER HAND IN GLOBAL COMPETITION —

Jian Zhao
Consumer Innovation Dept., Technology & Innovation Studies Div.
Mitsui & Co. Global Strategic Studies Institute

SUMMARY

- Although lithium-ion batteries (LiB) are currently the most popular and regularly used batteries, their dependence on rare earth metals as an ingredient material gives rise to concerns about the stability of material procurement in the future. Meanwhile, sodium-ion or Na-ion batteries (NiBs) are attracting attention as one of the next-generation battery candidates because of the abundance of material resources and low cost.

- The Chinese government is supporting the development of the country's NiB industry with a view to securing a stable supply of batteries and taking the lead in the development of next-generation batteries. Chinese companies are actively collaborating in capital and technology alliances to realize early mass production.

- While NiBs will not immediately replace LiBs, their adoption is expected to spread, beginning with applications that particularly require cost performance, such as for electric two- and three-wheeler vehicles, low-speed EVs, and stationary storage batteries. Despite lingering uncertainties about market prospects, companies in Western countries as well as in India are making moves to enter the business, seeing the future potential of NiBs.

1. NA-ION BATTERIES DRUMMING UP INTEREST

Although lithium-ion batteries (LiBs[1]) are widely used in many fields, they are dependent on rare earth metals as a material, whose production regions are unevenly distributed throughout the world. The recent increase in EV sales and the current crisis in Ukraine have caused prices of key raw materials for LiBs, such as lithium, to skyrocket, highlighting the importance of reducing material procurement risk in the development of next-generation batteries. Although R&D for sodium-ion or Na-ion batteries (hereafter referred to as NiBs[2]) has been ongoing since the 1980s, NiBs have not seen widespread use because they are inferior to LiBs in terms of energy density[3] and other performance characteristics. However, in response to the aforementioned changes in the market environment, the NiB has come to attract interest as a promising next-generation battery candidate because its main raw material, sodium, is 1,000 times more abundant in the earth's crust than lithium, and is not unevenly distributed in specific countries and regions as in the case of lithium. In its Global Energy Storage Outlook published at the end of 2021, BNEF[4] states that NiBs could play a meaningful role by 2030.

1 Abbreviation for lithium-ion battery.
2 Abbreviation for Na-ion battery; also referred to as sodium-ion battery (SiB).
3 The amount of energy that can be extracted per unit mass or unit volume of a battery, expressed in units such as Wh/kg, Wh/L.
4 Bloomberg New Energy Finance, a leading energy market research firm

Under these circumstances, NiB-related companies around the world are now competing in R&D to promote practical application of NiBs on a commercial scale, especially in China, where initiatives toward achieving early mass production are gaining momentum. This report discusses the latest trends and future prospects for NiBs.

2. KEY RAW MATERIALS, PERFORMANCE CHARACTERISTICS, AND POSSIBLE APPLICATIONS OF NA-ION BATTERIES

The operating principle of the NiB is the same as for the LiB, and in order to replace lithium ions with sodium ions as charge carriers inside the battery, it is necessary to develop new cathode and anode materials and electrolytes that can bring out the performance of those materials. Meanwhile, materials used in current collectors, separators, and other components of LiBs can be used for NiBs. The most promising candidate materials and their characteristics are shown in Figure 1.

Figure 1: Candidates for key materials for Na-ion batteries

Na-ion battery candidate material		Material characteristics and main advantages and disadvantages
Cathode material	Layered oxides (e.g., NaxMO2, 0<X≤1, M (transition metals) = Mn, Fe, Cr, Ni)	Large theoretical capacity. However, it has a short cycle life because its structure is easily destabilized by the adsorption/desorption of sodium ions during charging and discharging.
	Polyanionic compounds (e.g., NaFePO4, Na3V2(PO4)3, etc.)	High voltage and structural stability. However, gravimetric energy density and ionic conductivity are lower than layered oxides. In addition, vanadium compounds are toxic.
	Prussian blue analogues (Na2M'[M(CN)6]1-y-zH2O, M and M' (transition metals) = Fe, Co, Mn, Ni)	High gravimetric energy density. However, volumetric energy density is lower than layered oxides, and there is a risk of generating toxic hydrogen cyanide (HCN).
Anode material	Hard carbon	High capacity and low cost. However, there are safety issues because the charge reaction potential is very close to the deposition potential of metallic sodium. R&D is underway to enable storage of more sodium ions.
	Soft carbon	Higher voltage than hard carbon, but has the disadvantage of lower capacitance.
	Prussian blue	Characterized by high current and long cycle life. However, it has the lowest energy density of the various candidates.
Cathode current collector	Aluminum foil	Materials for currently available LiBs can be used.
Anode current collector	Aluminum foil	As aluminum does not react with sodium in an alloying reaction, it can be used as an alternative to the costly copper foil used in LiBs.
Separator	Polyolefin	Materials for currently available LiBs can be used.
Electrolyte	Sodium salts such as NaClO4 and NaPF6	NaClO4 comes with the risk of explosion, and NaPF6 comes with the risk of reacting with water to generate toxic hydrogen fluoride.
Electrolytic solution	Organic solvents such as dimethyl carbonate (DMC)	Materials for currently available LiBs can be used.

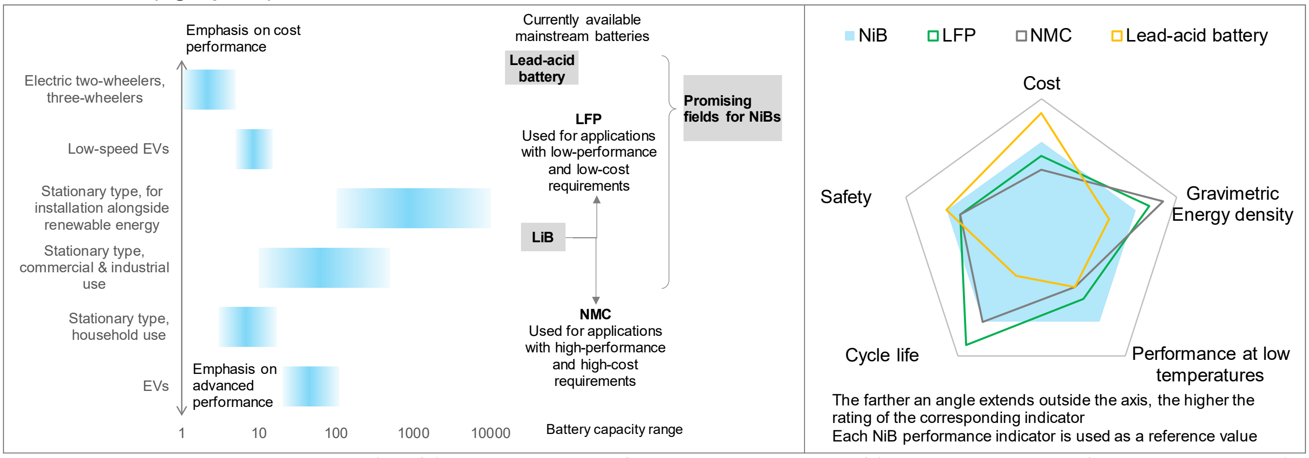
Source: Compiled by MGSSI based on an article published in Science Direct, "Exploits, advances and challenges benefiting beyond Li-ion battery technologies" (https://doi.org/10.1016/j.jallcom.2019.153261, accessed April 26, 2022); CIC energi GUNE blog post, "Achievements and challenges of sodium-ion battery materials" (https://cicenergigune.com/en/blog/achievements-challenges-sodium-ion-battery-materials, accessed April 26, 2022); and information available on Faradion Limited's website

There are several candidates for the cathode material, with the three most promising being large-capacity layered oxides, highly stable polyanionic compounds, and high energy-density Prussian blue analogues. As for the anode material, sodium ions are larger than lithium ions and cannot be intercalated into graphite, which is used for the LiB's anode, so it is necessary to develop a new anode material. Among the carbon-based (hard carbon, soft carbon) materials, Prussian blue, and other candidates, hard carbon has been adopted by many NiB developers because of its large capacity and low cost. Regarding the development of new electrolytes that can be adapted to NiB electrode materials, NaClO4 and NaPF6 are currently the most promising from a performance standpoint, but safer materials such as aqueous electrolytic solutions and all-solid-state electrolytes are also being developed.

The cost of NiB materials is expected to be 30-40% lower than that for LiB materials because the sodium, metals, carbon materials, etc. used in the NiB materials described above are abundant and easy to procure.

NiBs have advantages and disadvantages, such as excellent performance in low-temperature environments and charging speed, but low energy density. As shown in Figure 2, NiBs are not expected to replace LiBs in the near term for EVs and other applications that require advanced performance, but their use is expected to spread to electric two-wheelers and three-wheelers, low-speed EVs[5], and stationary storage batteries[6] as cost performance is a focal point in those applications. When compared to lead-acid batteries and lithium iron phosphate batteries (LFP), both of which are already widely used in these fields, NiBs are likely to compete for market share because they are significantly superior in all aspects (except cost) in the case of lead-acid batteries. Although their energy density is lower than that of LFP, NiBs are superior in terms of performance in low temperature environments and cost.

Figure 2: Promising fields of application for Na-ion batteries (left panel) and performance comparison with lithium-ion and lead-acid batteries (right panel)



Note: LFP is a lithium-ion battery that uses iron phosphate (LiFePO4) as the cathode material. NMC is a lithium-ion battery that uses NMC (a compound mainly composed of nickel, manganese, and cobalt) as the cathode material.

Source: Compiled by MGSSI based on an article published in Science Direct, "Exploits, advances and challenges benefiting beyond Li-ion battery technologies" (https://doi.org/10.1016/j.jallcom.2019.153261, accessed April 26, 2022); a study conducted by Deloitte Consulting China, "China Lithium Industry Deloitte POV 2.0: "Battery of the Time", (https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/strategy/deloitte_cn_lithium_pov_%202_en_20220406.pdf, accessed April 28, 2022); and information available on Faradion Limited's website

Figure 3 lists the world's leading NiB developers and their main battery materials, battery performance, expected applications, and mass production plans. Each company is developing its own technology to match the expected application of its product, in an environment where multiple candidate materials are available. Faradion (UK), for example, is focusing on achieving high energy density, while the Natron Energy (US) is pursuing the development of a battery with a long cycle life. As for mass production plans, Chinese companies, including CATL, which announced that it will launch the commercial marketing of its first product by 2023, all plan to achieve commercialization within the first half of the 2020s, earlier than Western companies, making it clear that efforts toward mass production in China will accelerate.

[5] Also called LSEV (low-speed electric vehicle). Generally, this term refers to ultra-compact EVs with a speed of 60 km/h or less and a cruising range of 100 km or less on a full charge.

[6] Storage batteries installed in residences, industrial facilities, renewable energy power plants, etc. for such purposes as emergency power supply and primary storage of electricity.

Figure 3: Product details, expected applications, and mass production plans of leading Na-ion battery developers

Company	Country	Cathode material	Anode material	Cell energy density (Wh/kg)	Charge/discharge cycle life	Operating temperature range	Expected applications	Mass production plan (Note 2)
Faradion Limited (Note 1)	UK	Layered oxide	Hard carbon	155	3,000 cycles	-20 –60	Low-speed EVs, stationary storage batteries	Giga-factory planned in India
Natron Energy	US	Prussian blue analogues	Prussian blue analogues	20–30	50,000 cycles	-20 –40	Stationary storage batteries for data centers and telecommunication facilities, industrial vehicles	0.6 GW/year in 2023
HiNa Battery Technology(中科海鈉)	China	Layered oxide	Soft carbon	145	4500 cycles	-40 –80	Electric two-wheelers, low-speed EVs, stationary storage batteries	1 GWh/year in 2022; eventually increasing to 5 GWh/year in the long term
CATL	China	Prussian blue analogues	Hard carbon	160	Undisclosed	-20 –Undisclosed	EVs, stationary storage batteries	2023
Tiamat Energy	France	Polyanionic compound	Hard carbon	90–120	5,000 cycles	Undisclosed	Scooters and other mobility vehicles, stationary storage batteries	6 GWh/year by 2030
Li-Fun Technology (立方新能源)	China	Layered oxide	Hard carbon	140	4,000 cycles	-20 –Undisclosed	Low-speed EVs, EV buses, stationary storage batteries for household use	2023
Nippon Electric Glass	Japan	Crystallized glass	Crystallized glass	Undisclosed	Undisclosed	-60 –120	Automotive and stationary storage batteries	2025
ZOOLNASM (江蘇衆鈉能源科技)	China	Polyanionic compound	Hard carbon	Undisclosed	Undisclosed	Undisclosed	Electric two wheelers, low-speed EVs, forklifts, stationary storage batteries	2023
Natrium Energy (鈉創新能源)	China	Layered oxide, also developing polyanionic compound	Hard carbon	130–160	5,000 cycles	-40 –80	Stationary storage batteries, electric two wheelers/three wheelers, low-speed EVs	Launch in 2022; targeting 80,000 mt of cathode and anode materials/year in mid term

Note 1: At the end of 2021, Reliance New Energy Solar Ltd., a wholly owned subsidiary of India's largest conglomerate Reliance Industries Ltd., acquired all of the shares of Faradion Limited.
Note 2: 1 GWh ＝1,000 MWh = 1,000,000 kWh; 1 GW = 1,000 MW = 1,000,000 kW
Source: Compiled by MGSSI based on information available on the websites of each company, CIC energi GUNE blog post "Achievements and challenges of sodium-ion battery materials" (https://cicenergigune.com/en/blog/achievements-challenges-sodium-ion-battery-materials, accessed April 26, 2022) and SMM NEWs(https://news.metal.com/newscontent/101860656/natrium-energy-signed-a-contract-of-80000-mt-of-sodium-ion-battery-cathode-material-project-further-accelerating-the-industrialisation, accessed July 14, 2022)

3. CHINESE GOVERNMENT BACKING GROWTH OF THE NA-ION BATTERY INDUSTRY

3-1. Why focus on Na-ion batteries?

Behind the acceleration of Chinese companies' efforts toward NiB mass production are government measures aimed at ensuring a stable supply of batteries and maintaining leadership in the battery industry.

China's goal of achieving net-zero emissions by 2060 requires a low-cost and stable supply of rechargeable batteries for the introduction of large amounts of renewable energy and the electrification of the mobility sector. However, domestic production of lithium, the main material for LiBs, accounts for only 9% of the world's total, making it vital for China to develop rechargeable batteries that do not depend on rare earth metals.

Since some of the LiB production equipment can be repurposed for NiB production, the hurdle to achieving mass production is considered to be low. If China takes the lead in mass production and commercialization, it may assume leadership in the NiB industry through the formation of supply chains, acquisition of know-how, and establishment of de facto technology standards.

3-2. A series of policies announced to boost the development of the Na-ion battery industry

In addressing the proposal to accelerate the development of the NiB industry, which was presented at the Chinese People's Political Consultative Conference[7] in August 2021, the Chinese Ministry of Industry and

[7] The Chinese People's Political Consultative Conference is one of China's basic political institutions and an organization of the United Front system, a political strategy based on the multiparty cooperation and political consultative system led by the Chinese Communist Party. It consists of representatives of the Communist Party of China, various democratic parties, independents, social organizations, various ethnic minority groups, various sectors of society, etc., and submits opinions and discusses major national and

Information Technology's[8] official response (Figure 4) covered technology development, deployment for demonstration and implementation, standards establishment, support for business model formation, and other areas, and the battery industry took it as a signal of government support for NiB industry development. Consequently, concrete plans for technology development and large-scale pilot projects were announced one after another, and the initiatives have steadily begun to move into the implementation phase.

Figure 4: Main policies to support China's Na-ion battery industy announced by the Chinese government since 2021

	Name of policy, etc.	Key details
July 2021	Guidance on Accelerating the Development of New Energy Storage by the National Development and Reform Commission and National Energy Administration	Accelerate NiB scaling demonstrations and pilot schemes
August 2021	Ministry of Industry and Information Technology's Response to Proposal No. 4815 of the Fourth Session of the 13th National Committee of the Chinese People's Political Consultative Conference (CPPCC)	1 Incorporate NiB into the national technology development plan to scale up, reduce costs, and improve performance with the aim of achieving high-quality development of the industry by 2025 2 Support implementation of R&D results. Promote adoption and full commercialization of NiBs, focusing on renewable energy power plants, mobility vehicles, telecommunications base stations, etc. 3 Promote the creation of NiB-related standards when the time is right 4 For companies and products entering the NiB market in early stages, provide support for the development of technologies and formation of commercial models
December 2021	China's 14th Five-Year Plan for Scientific and Technological Innovation in the Energy Sector	The plan designates NiB R&D as a focus area, identifying it as one of the next generation energy storage technologies
March 2022	China's 14th Five-Year Plan for New Energy Storage Development and Implementation	Accelerate research on NiB core technologies, related facilities and systems, and carry out technology demonstrations to diversify storage technologies by 2025
March 2022	Guidelines for applying for National Priority Projects in the field of "Energy Storage and Smart Grid Technology" (public comment version)	By 2025, develop a "100 MWh class NiB energy storage system" and conduct large-scale energy storage demonstrations, such as for industrial applications, aiming to achieve the following goals. Technical targets: Cell energy density of 150 Wh/kg or more, capacity retention of 80% or more at -40°C, cycle life of 10,000 cycles or more, cell cost of RMB 0.3 (approximately JPY 6)/Wh, etc.

Source: Compiled by MGSSI based on information made available by the Chinese government

4. CHINESE COMPANIES EYEING EARLY MASS PRODUCTION

Chinese NiB companies, including CATL, are actively pursuing capital and technology tie-ups amongst themselves in an effort to realize mass production at an early date (Figure 5).

HiNa Battery, which became independent from the Institute of Physics of the Chinese Academy of Sciences[9] in 2017, is one of the most notable NiB startups, having been the first in the world to demonstrate NiB-equipped low-speed EVs and 1 MWh energy storage systems. The company has announced a JV project with China Three Gorges Corporation, China's largest renewable energy power generation company, to establish a 1 GWh/year mass production structure and begin operation by the end of 2022, and has also received financial support from an investment fund affiliated with telecommunications equipment giant Huawei.

With an eye on the future potential of NiBs, companies with operations related to rechargeable batteries, such as material manufacturing and utilization services, are also actively participating in the market. Huayang New Materials Technology, a major coal, chemicals, and building materials company, and CRRC Group Corporation,

local issues at the annual plenary meeting of China's national legislature. (Source: Compiled by MGSSI based on information on the website of the Embassy of the People's Republic of China in Japan)

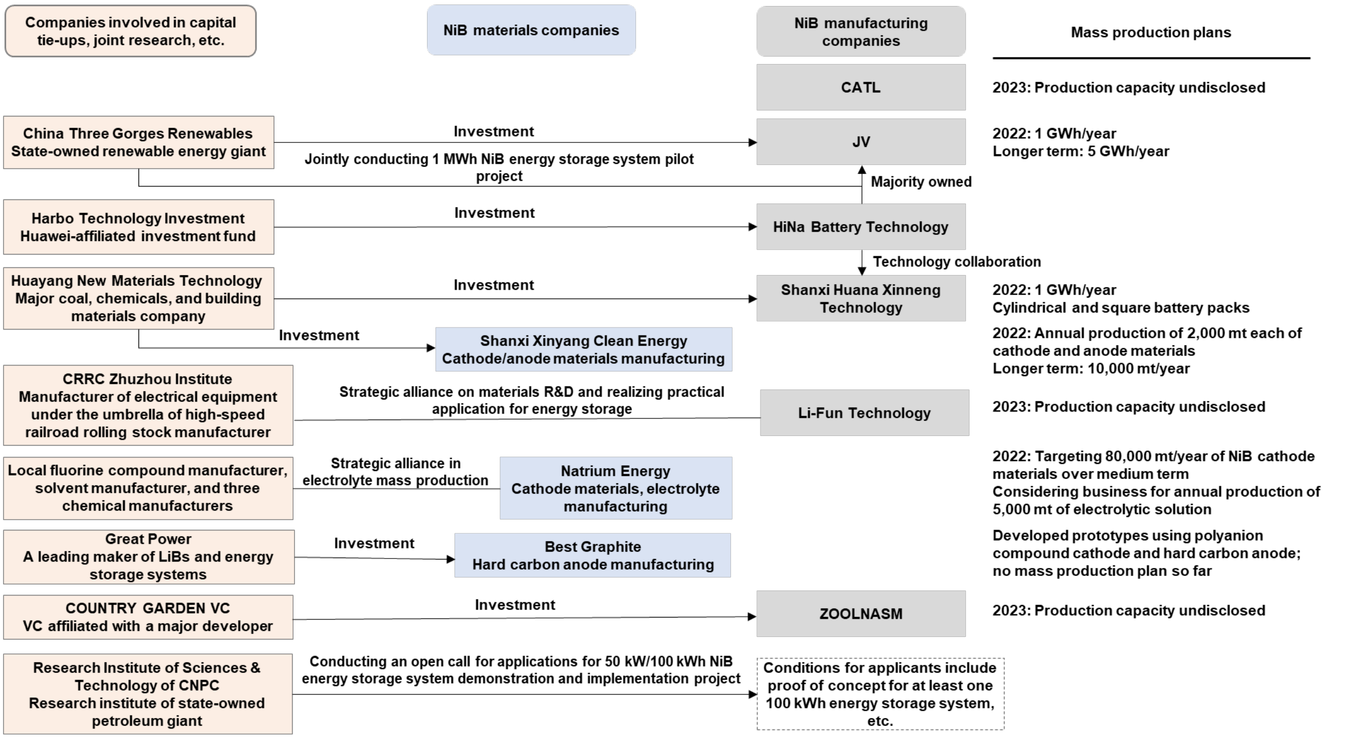
[8] It is one of the ministries under the State Council of the People's Republic of China, and its main areas of jurisdiction are the nation's industrial branches and the information industry.

[9] China's highest-level scientific and technological academic institution and comprehensive natural science and high-tech research center. (Source: Science Portal China, Japan Science and Technology Agency)

the largest manufacturer of high-speed railroad rolling stock in China, have also entered the market in the form of technical cooperation and strategic alliances.

Meanwhile, since the development structure and the supply chain for electrode materials and electrolytes to further exploit the performance of NiBs are not yet fully developed in China, joint development and collaboration among Chinese supply chain companies will also pick up momentum in the race toward realizing mass production. There are some moves that are seen as milestones, such as the strategic alliances formed between Natrium Energy and local chemical companies to mass produce electrolytic solution, and the investment by Great Power, a leading LiB and energy storage system company, in a hard carbon anode startup.

Figure 5: Collaboration among companies involved in Na-ion batteries and their plans for mass production



Source: Compiled by MGSSI based on information disclosed by each company and SMM NEWs

5. LOOKING AHEAD

5-1. Companies from other countries embarking on NiB business initiatives

The Chinese market, which is rushing to mass production, will offer business opportunities for companies in developed countries that have long been involved in NiB research, particularly in connection with introducing materials and individual components. Altris (Sweden), which has developed its own NiB cathode materials (Prussian white), established a base in Guangzhou at the end of 2021 with the aim of developing sales channels in the growing Chinese market. The company raised €9.6 million in Series A funding in March 2022, and is said to have plans to expand production capacity for its innovative battery cathode material to 2,000 metric tons/year (equivalent to approximately 1 GWh of NiBs) within two years. Japanese companies, which are world leaders in research on high-performance anode materials, electrolytes, and other materials for NiBs, are also expected to be presented with commercial opportunities.

Outside of China, other countries have also recognized the potential of NiBs and are moving toward mass production. A company under the umbrella of Reliance Industries, India's largest conglomerate, bought out Faradion (UK) at the end of 2021 and plans to use the acquired technology at its proposed giga-factory in India. In May 2022, Natron Energy (US) announced that the company and Clarios, a US major automotive lead-acid battery manufacturer, will begin mass production of NiBs in 2023.

5-2. Market prospects and the future

Even if early mass production of NiBs is achieved in China, it will still take time to form a supply chain, ensure stable quality, and realize cost advantages. The “White Paper on the Development of Sodium Ion Battery Industry in China (2022)” published by EVTank, an emerging industry research institute in China, estimates the value of the market that could theoretically be targeted by NiBs, including applications for electric two-wheelers, low-speed EVs, and stationary storage batteries, could grow to RMB 150 billion (approximately JPY 3 trillion; RMB 1 = JPY 20) by 2026, but avoided making clear NiB market share forecasts and expressed a cautious view, stating that full-scale market penetration would not occur until 2025 or later. Verified Market Research, meanwhile, estimates the global NiB market will reach a value of US$2.5 billion a year in 2028.

While the existing LiB market is expanding, the outlook for the NiB market is uncertain and it is unlikely to become a gigantic market anytime soon. However, in countries like India and China, where the market is huge and strong demand for mobility electrification and renewable energy is expected, the potential for NiBs with high cost performance is great. If costs can be lowered and appropriate supply chains are established by the increased utilization in these regions, further expansion of the NiB application fields and regions can be expected. Not only does China have a number of favorable conditions for fostering the NiB industry, including policy support, an existing battery industry base, and a huge domestic market, but it is set to make preemptive moves toward grabbing the leadership in the industry by establishing relevant technology standards and introducing policies to support business model formation in stages by 2025. As Western countries, India, and other nations will direct more attention to the NiB business going forward, their efforts are likely to fuel heated competition to achieve practical application of NiBs.