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Development Strategies of New Energy Materials for Carbon Peak and Neutrality—Case Study of Songshan Lake Materials Laboratory

Ximei QIU
Songshan Lake Materials Laboratory, Dongguan 523808, China, Shuqxm@sslab.org.cn

See next page for additional authors

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Abstract

Transformative energy technologies will provide strong strategic support to the realization of peaking carbon dioxide emissions before 2030, and achieving net zero carbon emissions before 2060. Reducing the dependence on fossil fuels by saving energy and reducing emissions from the source is essential to achieve the double-carbon target as soon as possible. Songshan Lake Materials Laboratory is working on key materials to develop solar-battery power systems and electrification of transportation energy to return coal, oil, and natural gas from fuels to materials. This study focuses on introducing the research team of its New Energy Materials and Devices R&D Center with the whole chain innovation mode from research to technology transfer/transformation. Example works of new materials for High Efficiency Crystalline Silicon Solar Cells Group, Li-ion Battery Materials Group, Flexible & Zinc Battery Group are introduced. To get through "the last mile" of technology transformation, research projects and pilot lines have been set up to make new energy materials and devices into products in the past three years, and work together with industrial partners in an innovative workshop cluster model. It is suggested to make overall planning, provide stable support to the research and development, and create a cluster development model with R&D center-innovative workshopsindustrial parks.

Keywords

new energy materials; crystalline silicon solar cells; lithium-ion power batteries; zinc-based energy storage batteries

Authors

Ximei QIU, Yan WANG, Haiming LYU, Jian XU, Yida WU, Xiaowei MA, Chunyi ZHI, Xiaolong DU, and Xuejie HUANG

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Development Strategies of New Energy Materials for Carbon Peak and Neutrality—Case Study of Songshan Lake Materials Laboratory

QIU Ximei[1], WANG Yan[1,2], LV Haiming[1], XU Jian[3], WU Yida[1], MA Xiaowei[1], ZHI Chunyi[1,4], DU Xiaolong[1,2], HUANG Xuejie[1,2]

1. Songshan Lake Materials Laboratory, Dongguan 523808, China;
2. Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China;
3. Guangdong Songhu Material Industry Development Center Co., Ltd., Dongguan 523808, China;
4. City University of Hong Kong, Hong Kong 999077, China

Abstract: Transformative energy technologies will provide strong strategic support to the realization of peaking carbon dioxide emissions before 2030 and achieving net zero carbon emissions before 2060. Reducing the dependence on fossil fuels by saving energy and reducing emissions from the source is essential to achieving the "double carbon" target as soon as possible. Songshan Lake Materials Laboratory is working on key materials to develop solar-battery power systems and electrification of transportation energy to return coal, oil, and natural gas from fuels to materials. This study focuses on introducing the research team of New Energy Materials and Devices R&D Center with the whole-chain innovation mode from research to technology transfer/transformation. Example works of new materials of High Efficiency Crystalline Silicon Solar Cells Group, Li-ion Battery Materials Group, and Flexible & Zinc Battery Group are introduced. To get through "the last mile" of technology transformation, research projects and pilot lines have been set up to make new energy materials and devices into products in the past three years, and work together with industrial partners in an innovative workshop cluster model. It is suggested to make overall planning, provide stable support to the research and development, and create a cluster development model with R&D center-innovative workshops-industrial parks. **DOI:** 10.16418/j.issn.1000-3045.20211208009-en

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1 "Double carbon" target and energy consumption

On September 22, 2020, President Xi Jinping announced at the general debate of the 75th session of the United Nations General Assembly that "China will scale up its nationally determined contributions and adopt more vigorous policies and measures to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060" (hereinafter referred to as "double carbon" target). According to the data on carbon emissions, power generation/heating, industry, and transportation are the top three sections responsible for CO_2 emissions in China [1]. Therefore, appropriate measures to achieve the "double carbon" target include expanding the proportion of renewable energy and the use of decarbonized transportation.

Among renewable energy sources, solar energy has become the fastest growing green energy source because of cleanliness, safety, and unlimited reserves. Crystalline silicon solar cells have always occupied an absolute dominant position (about 90%) in the photovoltaic industry. They represent an important area in the current international competition for new energy and play a critical role in China's renewable energy strategy. Automobile electrification and intelligentization are inevitable, and the rapid development and large-scale application of new energy vehicles will greatly reduce fuel consumption. In November 2020, the General Office of the State Council issued the New Energy Automobile Industry Development Plan (2021–2035) to promote the high-quality development of new energy automobile industry and build up the automobile industry of China. The sales of new energy vehicles are expected to reach about 20% of the total sales of new cars by 2025. By 2035, pure electric vehicles are expected to dominate the sales of new vehicles, and public transportation will be fully electrified. At present, fossil fuels still account for more than 80% of energy consumption in China. In the future, solar and wind power generation will occupy an increasingly important position under the guidance of the "double carbon" target. High-safety zinc battery energy storage technology will mitigate the intermittency and variability of wind and solar energy [2]. This will promote the development and large-scale application of solar

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Corresponding author: HUANG Xuejie, E-mail: huangxuejie@sslab.org.cn

and wind power generation technologies, and realize complementary and mutual promotion of technologies.

The electrification of automobiles requires green power to help achieve the "double carbon" target. Photovoltaic power generation and energy storage technologies are the main solutions, and the integration of "light energy–energy storage–energy distribution–energy use" green power chain is the key to achieving the "double carbon" target. China has achieved "corner overtaking" in photovoltaics, new energy automobiles, and energy storage. This is mainly attributed to the improvement of basic industry, the huge market demand, the continuous improvement of supply chain, the progress of research and development, and the increased level of equipment localization. These achievements have drastically reduced production costs in the aforementioned fields. However, further efforts are needed in materials used in high-efficiency crystalline silicon solar cells, lithium-ion power batteries, and zinc-based energy-storage batteries, to achieve greater breakthroughs and better serve the energy revolution and the "double carbon" target.

2 Current situation and trend of new energy materials and technologies

2.1 Photovoltaic power generation: crystalline silicon solar cells

After more than 20 years of development, the photovoltaic industry has become one of the few strategic emerging industries in China with international competitive advantages and an important engine to fuel China's energy revolution. At present, China's photovoltaic industry has established the whole industrial chain consisting of silicon materials, silicon wafers, solar cells, modules, and power generation systems, with the manufacturing scale, industrialization technology level, and industrial system construction ranking first in the world (Table 1).

With supporting policies, China's photovoltaic industry has made rapid progress and has caught up with the developed countries in terms of production capacity, making great contributions to the reduction of the levelized cost of photovoltaic power generation in the world (Figure 1). However, there are still bottlenecks such as lack of original innovation and dependence on foreign technologies. Taking the highly technology-driven solar cells as an example (Figure 2), the commonly used passivated emitter and rear contact (PERC) technology as well as the structure design and manufacturing processes of the next-generation high-efficiency cells such as tunneling oxide passivating contact (TOPCon) solar cells, heterojunction (HJT) solar cells, and interdigitated back contact (IBC) solar cells were developed in foreign countries. HJT is the most popular technology and has remarkable advantages such as high mass production efficiency and short production process. HJT was invented by Sanyo in Japan in 1990 and was developed and promoted in China after the patent expired in 2015. At the early stage of promotion of these high-efficiency cell technologies, the key manufacturing and testing equipment relied on imports. Even the key auxiliary materials (e.g., additives and pulps) were mostly imported. Most technologies developed in China were not original. With the rapid development of photovoltaic industry in China, the market demand of independent technologies is increasing. On the basis of digestion and absorption, some leading enterprises are increasing R&D investment and promoting technology upgrading. China has the largest scale of photovoltaic industry, which provides a good opportunity for the development and industrial application of original technologies. Therefore, it is of great significance to establish an efficient development mode with the combination of industry, university, and research. China's photovoltaic industry should grasp the opportunities in the development of new energy offered by the "double carbon" target, and create an independent technology system through original innovation to continuously enhance the competitive advantage of China's photovoltaic products and eventually lead the development of photovoltaic technologies in the world.

2.2 Lithium-ion power batteries

Lithium-ion batteries were industrialized in the early 1990s and have since developed rapidly because of high working voltage, high energy density, long cycle life, high charge speed, high discharge power, low self-discharge rate, no memory effect, and environmental friendliness. According to different application scenarios, the global market of lithium-ion batteries can be divided into three segments: power, consumption, and energy storage. Lithium-ion power batteries are mainly used in new energy vehicles, electric bicycles, electric tools, and special vehicles.

Table 1 Global photovoltaic production capacity, output and proportion of Chinese products in the world in 2020

Indicator	Polysilicon	Silicon wafers	Solar cells	Modules
Global production capacity	6.08×10^5 t	247.4 GW	249.4 GW	320.0 GW
China's share of global production capacity	75.2%	97.0%	80.7%	76.3%
Global output	5.21×10^5 t	167.7 GW	163.4 GW	163.7 GW
China's share of global output	76.0%	96.2%	82.5%	76.1%

Data source: China Photovoltaic Industry Association, April 2021

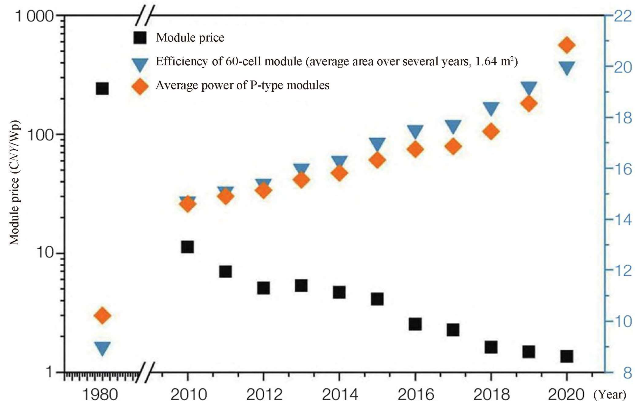

Figure 1 Development of price, efficiency, and power of Si-based PV modules ①

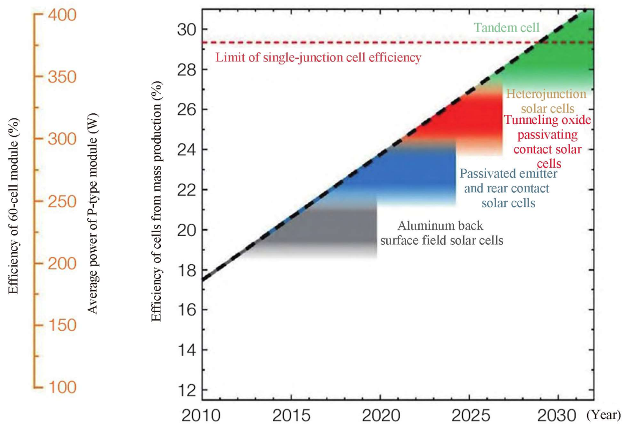

Figure 2 Roadmap of PV cell technologies ②

The annual global sales of new energy vehicles reached 3.24 million in 2020 with a year-on-year increase of 43%. The global market of lithium-ion batteries was about 53.5 billion USD, 19% higher than that in 2019 (Figure 3). About 6.5 million new energy vehicles were sold globally in 2021, with a year-on-year increase over 100%. In 2021, the cumulative output of power batteries in China was 219.7 GWh, achieving a cumulative year-on-year increase of 163.4%. The plans for the development of new energy vehicles in various countries have ensured the market of power batteries. Global lithium-ion batteries are expected to enter the TWh era in 2025. The global market of lithium-ion batteries is expected to exceed 100 billion USD. China will be the largest single country market for new energy vehicles.

Lithium-ion batteries are mainly composed of five parts: cathode material, anode material, separator, electrolyte, and battery shell. Cathode material accounts for 30%–40% of the cost of lithium-ion battery materials and directly determines the overall cost of the battery. Power batteries will dominate the lithium-ion batteries in the next decade, and the development of cathode materials experienced three generations (Figure 4). (1) The first generation is represented by lithium manganese oxide. Lithium manganese oxide battery with a nominal voltage of 3.7 V is widely used in light vehicle market because of its low cost, high safety, and good low-temperature performance. (2) The second generation is represented by lithium iron phosphate and lithium nickel cobalt manganese (aluminum) oxide (ternary) batteries. Lithium iron phosphate battery with a nominal voltage of 3.2 V is characterized by low cost, high safety, environmental friendliness, and high-temperature resistance. However, it has low energy density and poor low-temperature

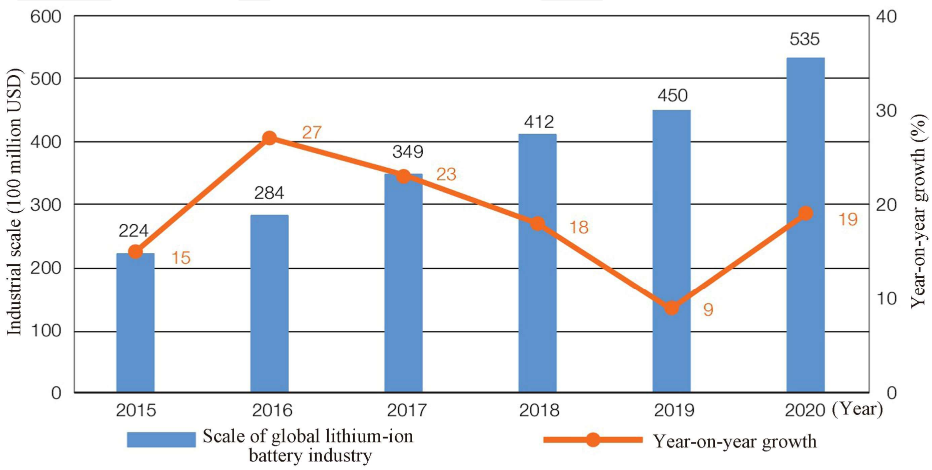

Figure 3 Global lithium-ion battery industry scale from 2015 to 2020

Data source: *White Paper on Development of Lithium Ion Battery Industry* (2021 Edition) by Electronic Information Research Institute of China Electronic Information Industry Development Institute, Released November 10, 2021

① International Technology Roadmap for Photovoltaics (ITRPV, 2021).
② Messmer C, Schön J, Lohmüller S, et al. How to make PERC suitable for perovskite-silicon tandem solar cells: A simulation study. 38th EUPVSEC, 6th September, 2021.

performance. Moreover, sustainable development may be a problem due to the high cost of lithium cobalt oxide and nickel manganese cobalt oxide with laminar structures commonly used as its high-capacity cathode materials, as well as the shortage of cobalt resources. (3) The third generation is represented by high-voltage lithium nickel manganese oxide and high-capacity low-cobalt/cobalt-free layered cathode materials. High-voltage lithium nickel manganese oxide battery has a nominal voltage of 4.5 V and the advantages of high energy density, wide operating temperature range, high safety, minimal lithium equivalent, and low cost. Mauler et al. [3] predicted that the cost of batteries based on advanced high-voltage or high-capacity materials can be reduced to 84 USD/kWh. However, the severe side reaction between lithium nickel manganese oxide and electrolyte and the damage from by-products to the entire battery system at high voltage have impeded their commercial applications. Stable anode materials, electrolyte interface membrane, and high pressure-resistant battery system are key solutions to this problem. Breakthrough of this bottleneck would balance high energy density and low cost. Meanwhile, the stable spinel structure and three-dimensional lithium-ion diffusion channel ensure high safety, excellent C rating, and high low-temperature performance. Compared with the commonly used lithium iron phosphate power battery, the energy density can be increased by more than 40%, and the working temperature can be lowered by 20 °C. In terms of the cost of raw materials, with the same consumption of lithium carbonate, the power output of high-voltage lithium nickel manganese oxide battery is about 35% higher while the total cost can be about 30% lower than that of lithium iron phosphate battery. Lithium nickel manganese oxide is the most promising cathode material for the next-generation lithium-ion batteries. Songshan Lake materials Laboratory has completed the pilot test and initiated the industrial application of this material.

2.3 Zinc-based energy storage batteries

The “double carbon” target is bound to accelerate the development of clean energy, and energy storage technology is needed to support the power system. Photovoltaic and wind power generation characterized by cleanliness, safety, and unlimited reserves will play an increasingly important role in new energy industry. There will be a new round of development in large-scale electrochemical energy storage technology, which must meet three basic requirements: high safety, high cost-effectiveness and low environmental load in the life cycle. At present, technically mature electrochemical energy storage technologies such as lithium-ion batteries and lead-acid batteries have been commercialized. With the iteration of energy industry, electrochemical energy storage technology has also evolved, and the traditional lead-acid battery market is gradually occupied by rechargeable batteries. Rechargeable zinc battery with aqueous electrolyte has attracted wide attention because of its environmental friendliness, non-toxicity, high capacity (819 mAh/g), fast charging/discharging, ultra-high safety, and low cost. However, in the industrialization of aquatic zinc ion batteries, the technologies are relatively mature and commercial products have been developed overseas, while the technical level remains to be improved in China. For example, the zinc-manganese and nickel-zinc batteries developed by Zincfive (the United States) have been commercialized. The life of product developed by Sunergy (French) can reach about 2 000 cycles. The rechargeable zinc batteries in China are still in research and development. For example, the rechargeable zinc batteries developed by Songshan Lake Materials Laboratory have initiated commercialization and a series of new products will be launched. Owing to the extremely high safety, zinc batteries can be used in the scenarios with harsh safety requirements in the future, outperforming lithium-ion and lead-acid batteries (Figure 5).

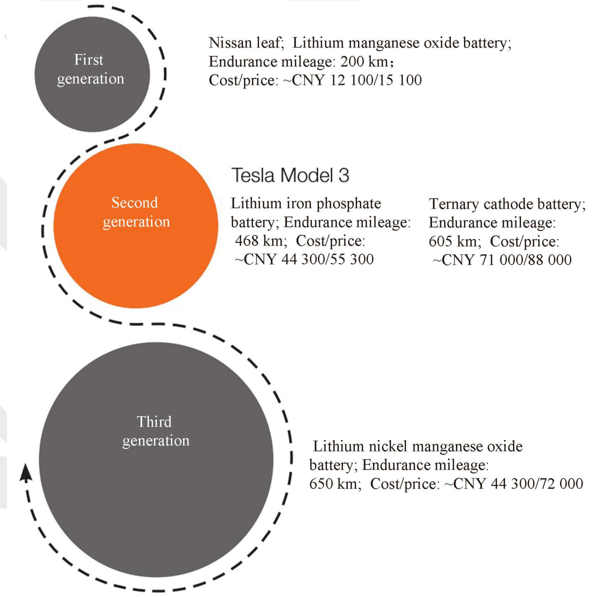

Figure 4 Generations of cathode materials catalyse iteration of power batteries

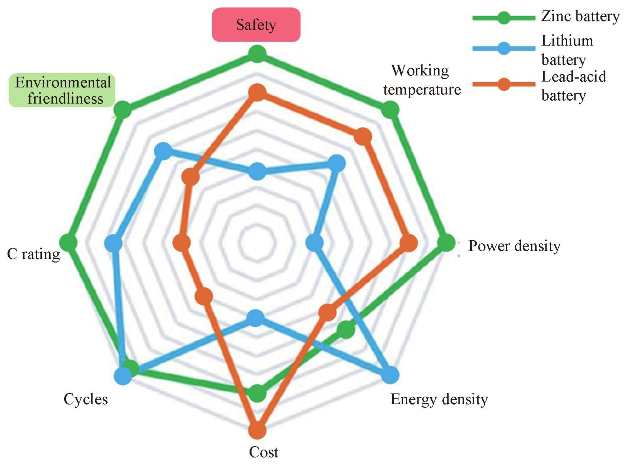

Figure 5 Performance comparison of zinc batteries, lithium batteries, and lead-acid batteries

According to the report on energy storage industry by Everbright Securities, the cumulative investment in energy storage industry will reach CNY 122 trillion in 2020–2060 (Figure 6) [③], and zinc batteries will account for about 30% of the investment. Zinc batteries are expected to occupy a large portion of the current lead-acid battery market in the future. They can be used not only in consumer electronics and large-scale energy storage power plants but also in extreme environments such as outer space and deep sea.

3 Songshan Lake Materials Laboratory aims at key technical difficulties and plays a leading role in industrial transformation of new energy materials

3.1 Research and development of key materials and technologies for crystalline silicon solar cells

(1) Consolidating basic research. Since 2009, the High Efficiency Crystalline Silicon Solar Cell Group at the Songshan Lake Materials Laboratory has focused on cost reduction, efficiency improvement, and green manufacturing and addressed the fundamental scientific questions of how to enhance light absorption and electricity collection of crystalline silicon solar cells. The Group has conducted research on the light-trapping micro-nano structure on the surface of crystalline silicon and on the contact properties of front/back electrodes, and achieved several innovations. In particular, important innovations have been made in texturing technologies based on nano-silver, nano-copper, and silver-copper catalytic etching. On the basis of revealing the mechanism of black silicon texturing, the Group has developed a variety of methods to regulate black silicon texturing structure and published a series of research papers, attracting attention from photovoltaic enterprises and research institutes worldwide. Meanwhile, by focusing basic research on industrial application, the Group investigated the key scientific issues in the process from experiments on small wafers to pilot production of large wafers, and assessed the mass producibility of related technologies. The experimental design was continuously optimized to control costs. Focusing on patent protection of core technologies, the Group has applied for more than 50 patents on texturing and black silicon solar cells, forming a complete patent system for core technologies of monocrystalline and polycrystalline black silicon solar cells.

(2) Accumulating industrialization experience. In 2016, after completing the reservation of basic research and technology, the High Efficiency Crystalline Silicon Solar Cell Group used the diamond wire cutting of silicon wafer to further reduce the cost of photovoltaic power generation. This posed a new challenge to the traditional texturing technology. Black silicon technology was used to solve the difficulty in texturing initiation and improve the battery efficiency. The Group used this opportunity to complete the design and construction of a pilot machine as well as the verification of medium- and large-scale production within two years. Finally, an additive for polycrystalline black silicon texturing was developed and commercialized. This product can improve the battery efficiency by 0.4% to reach the highest in the industry. The development of black silicon texturing technology from basic research in laboratory to industrialized application not only provides valuable experience in industrialization for the Group, but also exposes the key shortcomings, i.e., the lack of a complete pilot production line and the slow progress of industrialization.

(3) Establishing a whole-chain development mode. After enrollment in the Songshan Lake Materials Laboratory, the High Efficiency Crystalline Silicon Solar Cell Group immediately set up a pilot production line for the research and development of high-efficiency crystalline silicon solar cells. This provides a reliable platform for trial verification and

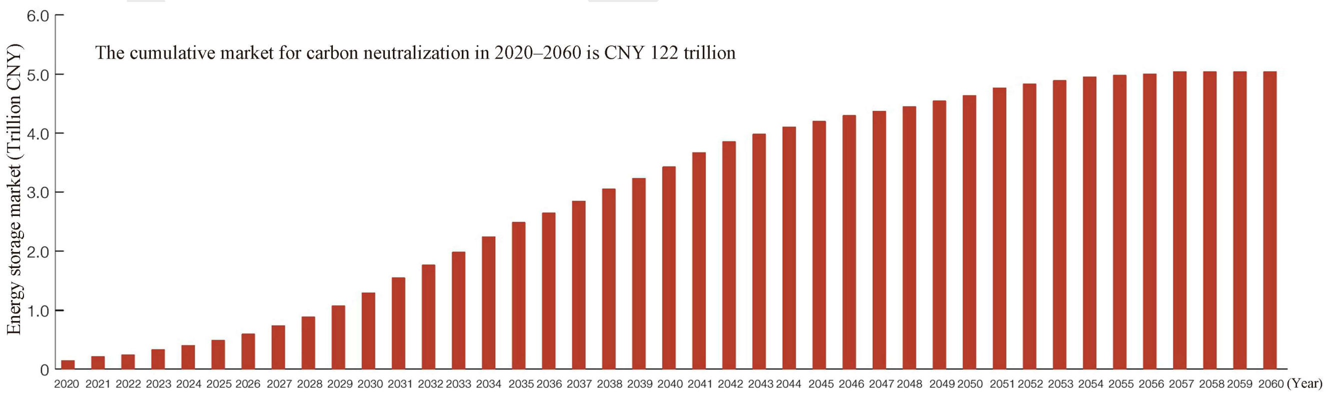

Figure 6 Energy storage investment market space from 2020 to 2060

③ Yin Z S, Ma R S, Hao Q, et al. Energy storage: a new track in carbon neutrality and an emerging trillion market. An in-depth report on carbon neutrality (III) by Everbright Securities. Published on March 10, 2021.

pilot production of innovative production processes, thus establishing a whole-chain development mode from basic research to industrialization. With the existing advanced surface texturing technology, the Group broadened the scope of research. They carried out application-oriented basic research for various surface/interface problems in crystalline silicon solar cells. Further, they used the pilot production line to conduct rapid mass producibility validation of the original research results and transform the basic research results to products, forming an effective research and development mode of basic research–mass producibility verification–product development. Under the guidance of this whole-chain research and development mechanism, the Group has successfully developed a series of crystalline silicon wet polishing additive products for acid polishing, alkali polishing, and texturing. Meanwhile, aiming at the difficulties in reflectance and appearance detection in battery production, the Group developed a silicon wafer reflectivity and appearance detector with a large detection area, high precision, and high speed to meet the needs of real-time, rapid, and accurate detection on photovoltaic cell production line. The Group takes basic research as the cornerstone and aims to develop original industrial technologies that can be applied in large-scale production. They are dedicated to improving the competitiveness of photovoltaic products in China, fueling the rapid growth of photovoltaic market, and providing scientific and technological support for the implementation of China's clean energy strategy.

3.2 High-voltage lithium nickel manganese oxide cathode material and battery technologies

The next-generation of power batteries has become a focus of global competition. The Li-ion Battery Materials Group of the Songshan Lake Materials Laboratory focuses on achieving the industrialization of high-voltage lithium nickel manganese oxide materials and the application of related battery technologies. They have first developed full battery based on high-voltage lithium nickel manganese oxide with long cycle life in the world.

(1) Solving basic scientific problems of materials and planning for patented core technologies of lithium nickel manganese oxide battery. Since 2019, the Li-ion Battery Materials Group has adopted innovative surface modification methods to synthesize surface-stabilized lithium nickel manganese oxide cathode materials. The development of high pressure-resistant electrolytes, modification of positive auxiliary materials, and optimization of binders have greatly improved the cycling performance of high-voltage lithium nickel manganese oxide battery under high temperature and high pressure [4]. The Group emphasizes on the protection of core intellectual property rights. A patent plan has been well established with a focus on the materials and technologies used in lithium nickel manganese oxide battery. At present, the Group has been granted with or been applying more than 50 patents, forming a relatively complete patent system including the core technologies. The project Third Generation of Lithium-ion Power Battery proposed by the Group was selected as one of the top 50 in start-up group at the 2021 High-value Patent Cultivation and Plan Competition in Guangdong-Hong Kong-Macao Greater Bay Area.

(2) Developing key technologies and achieving innovative technology development in the whole chain of material–electrode–battery. The third-generation power batteries based on high-voltage lithium nickel manganese oxide cathodes combine the high safety of lithium iron phosphate batteries and the high energy density of ternary cathode batteries. Specifically, they do not need cobalt, and have the lithium consumption 40% less than lithium iron phosphate batteries and 20% less than ternary batteries, which are critical for cost-effectiveness and supply chain security. By optimization of homogenization, coating, rolling, and equipment involved in the production of cathodes, the Li-ion Battery Materials Group has developed single-cell batteries with more than 40% improvement in energy density as compared with lithium-iron phosphate batteries. The power battery composed of lithium nickel manganese oxide and graphite developed by the Li-ion Battery Materials Group has a life of more than 3 000 cycles. This meets the requirements of new energy vehicle applications and is much higher than the 500 cycles reported worldwide. In addition, the material has high performance at low temperature and maintains 94% capacity at −25 °C. The high-voltage lithium nickel manganese oxide cathode material and battery technology were awarded as one of the seven frontier technologies in the 2020 World New Energy Vehicles Congress.

(3) Recognizing the great market potential of this industry and establishing a pilot production line of lithium nickel manganese oxide materials with high stability and long cycle life. At present, the pilot production line of lithium nickel manganese oxide material in Songshan Lake Materials Laboratory has been completed and put into operation. The pilot line has a production capacity of 500 kg, and realizes the batch production of lithium nickel manganese oxide with high stability and long cycle life (>5 000 cycles) for the first time in the world. The pilot battery production line established by the Li-ion Battery Materials Group has greatly promoted research/development and industrialization, and launched a new generation of power batteries through the application of new materials and technologies to boost the development of new energy vehicle industry.

3.3 Research and development of zinc-based battery technologies

The whole-chain development mode has to achieve the leap from research to industry, which requires complex industrial ecology and environment full of challenges. The whole-chain innovation mode of lithium-ion batteries proposed by the Institute of Physics, Chinese Academy of Sciences provides a model for the development of zinc-based batteries at the Songshan Lake Materials Laboratory [5].

(1) Attaching importance to original basic research. The Flexible & Zinc Battery Group at the Songshan Lake Materials Laboratory has been dedicated to the development and application of aqueous zinc-based batteries for years. The Group has accumulated rich experience in energy storage mechanism, electrode materials, super-flexible electrolytes, and device structure design, published a series of high-level research papers and been granted with a large number of patents. At the end of 2018, the industrial transformation of zinc-based batteries was initiated in the Songshan Lake Materials Laboratory, focusing on the exploration of cell preparation methods. Meanwhile, investment has been put in cathode load improvement, electrolyte formulation, and assembly process optimization.

(2) Moving from laboratory to factory to realize small-scale production. With continuous exploration and the maturation of electrode preparation, winding, and full battery manufacturing processes, as well as the application of newly developed zinc electrode formula and additives, the performance of zinc electrode and whole battery, especially the cycle life, has been significantly improved. The 1C charge-discharge cycle life of AA1200 cylindrical zinc battery has been increased to 400 cycles, and even more than 500 cycles in some individual batteries, which is a big improvement over the 100–200 cycles of the batteries in the market. In addition, the zinc electrode with a special formula makes the discharge plateau more advantageous and about 20 mV higher than the batteries in the market. Meanwhile, two square zinc-based batteries with capacities up to 15 Ah and 55 Ah are under development. The preliminary estimate is that the 55 Ah battery will have an energy density of 85 Wh/kg or 200 Wh/L.

(3) Promoting the construction of pilot production line. Through an in-depth analysis of the characteristics of nickel-metal hydride and nickel-cadmium battery production lines, as well as some advanced instruments used for lithium-ion battery production, a production line suitable for zinc-based battery production has been designed. Up to now, the cathode material preparation–pulping–electrode production line has been established for both cylindrical and square batteries. The anode material preparation–pulping–electrode production line for both cylindrical and square batteries has been debugged and will be put into use soon. The cylindrical battery assembly line will soon be ready for use after debugging to achieve preliminary production capacity. The square battery assembly line uses more manpower and is currently at the stage of manual + machine production, which remains to be improved. In the future, efforts will be made to improve the efficiency of production line and optimize the performance of battery by using various product and process parameters to enhance the product stability. The automation of the production line will be constantly upgraded for batch production of high-quality products in a more efficient way.

4 Strategies for the development of new energy industry in the Guangdong-Hong Kong-Macao Greater Bay Area

As important node cities in the Guangdong-Hong Kong-Macao Greater Bay Area, Shenzhen and Dongguan have attracted the largest number of new energy enterprises in China and have various application scenarios for the new energy industry. It is the right time to plan at the national level an international first-class research center and a high-tech industrialization highland. We therefore put forward the following two suggestions.

(1) Supporting the development of high-level research and development institutions. The Songshan Lake Materials Laboratory is one of the first batch of provincial laboratories established in Guangdong Province and an important platform supporting the “four beams and eight pillars” system of the Songshan Lake Science City. As an important research platform and a testing ground for institutional innovation in the construction of the early start-up area of the comprehensive national science center in the Greater Bay Area, the Innovation Model Factory Group of the Laboratory is striving to build the chain that connects basic and applied research. Technological progress has been made to promote the upgrading of new energy industries regarding high-efficiency crystalline silicon solar cells, lithium-ion power batteries, and zinc-based energy-storage batteries.

(2) Creating a cluster development model. The Guangdong-Hong Kong-Macao Greater Bay Area with a complete manufacturing system and good industrial supporting capability has formed a solid foundation and unique advantages in the construction of national large scientific devices and the development of industrial clusters. By creating a development model that involves a park composed of innovation workshops, we can gather leading scientists in China and from the world to work with enterprises to promote sustainable progress in the new energy industry.

References

1 China Electricity Council. China Electric Power IndustryAnnual Development Report 2021. Beijing: China Building Materials Industry Press, 2021. (in Chinese)

2 Li X F, Zhang H Z, Zheng Q, et al. Electrochemical energy storage technology in energy revolution. Bulletin of Chinese Academy of Sciences, 2019, 34 (4): 443–449. (in Chinese)

3 Mauler L, Duffner F, Wolfgang G Z, et al. Battery cost forecasting: A review of methods and results with an outlook to 2050. Energy Environmental Science, 2021, 14: 4712–4739.

4 Zhan Y J, Wu Y D, Ma X W, et al. 4.5 V Li-ion battery with a carbonate ester-based electrolyte. Energy Storage Science and Technology, 2020, 9 (2): 319–330. (in Chinese)

5 Wen Y, Huang X J, Zhu C L. Case study of lithium-ion battery research of Institute of Physics, Chinese Academy of Sciences: On model of whole-chain innovation of national research organization of China. Bulletin of Chinese Academy of Sciences, 2019, 34 (12): 1450–1457. (in Chinese)

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QIU Ximei, Engineer at Songshan Lake Materials Laboratory, mainly engaged in lithium ion battery materials and other related work. She participated in 6 National Key Research and Development Programs, Guangdong Provincial Key Field Research and Development Program, Shenzhen Science and Technology Program, etc. She owns 5 authorized invention patents and has participated in drafting 1 national standard. E-mail: Shuqxm@sslab.org.cn

HUANG Xuejie, Professor at the Institute of Physics, Chinese Academy of Sciences (IOP/CAS), Deputy Director of Songshan Lake Materials Laboratory, Director of Li-ion Power Battery Technology & Equipment Service Platform, Guangzhou Institute of Industrial Technology, and Vice President of China Battery Industrial Association. Since 1996, Professor Huang has been chairing the group of Solid State Ionics at IOP/CAS and working on the research, development, and industrialization of secondary lithium batteries and key related materials. He has published more than 200 peer-reviewed journal papers, and owned more than 30 patents. He has developed technologies for materials, batteries, and machines for Li-ion battery industry in China. He has also founded several companies to develop and produce large size Li-ion batteries for electrical vehicle and energy storage applications. E-mail: huangxuejie@sslab.org.cn

