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Development Strategies for New Energy Materials in China

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Abstract: New energy materials are important for strategic emerging industries in China and for economic and social development as well as national security. In this paper, we summarize the development of key materials for lithium-ion batteries and fuel cells in China and abroad and analyze problems of China's new energy materials industry, which include a lack of innovation, supply chain issues, and few platforms for collaboration among production, education, research, and application. Development trends for key materials are also forecast. We identify development targets for lithium-ion batteries and fuel cells by 2025 and 2035 and elaborate goals and key tasks. To achieve developmental advances, China should improve top-level planning and enhance support policies for innovation-driven development to foster competitive enterprises. It also should establish a production and application demonstration platform and strengthen talent development.
Keywords: new energy materials; lithium-ion battery; fuel cell; development strategy

1 Introduction

New energy materials are functional or structural–functional integrated materials that support the development of new energy or store and convert energy. New energy materials play an important role in promoting the development of new energy sources. The invention of new energy materials has given birth to new systems and improved the efficiency of such systems. The use of new energy materials directly affects the investment and operation costs of new energy systems [1]. Lithium-ion batteries are the most competitive energy storage technology available for new energy vehicles and power regulation. The hydrogen fuel cell is the core power generation unit of the hydrogen energy era. Therefore, this paper focuses on strategies of new energy material for lithium-ion batteries and hydrogen fuel cells.

According to global development trends, the United States, Japan, the European Union, and other developed countries and regions as well as emerging economies such as Russia, Brazil, India, and South Africa have successively implemented policies and measures to support industrial development of new energy materials, striving to seize a place in future international competition. Specifically, the United States has formulated major strategies such as the EV Everywhere Grand Challenge and Materials Genome Initiative and recently released a draft roadmap for its Energy Storage Grand Challenge. Japan has issued plans such as the *Research and Development Strategy of Nanotechnology and Materials* and *New Growth Strategy* [2]. The European Union has released the EU 2020 Strategy (Battery 2030+), regarding key new materials as important foundations of advanced manufacturing industries [3]. China introduced *China Manufacturing 2025* and the *Special Plan for Scientific and Technological Innovation in the Material Field During the 13th Five-Year Plan* [4,5] to promote structural changes in China's new

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energy materials industry, comprehensively reshape technological modes, and form an open and competitive development ecology.

After years of effort, China's new energy materials industry has achieved remarkable development. Technical levels are improving daily, and the industrial scale is constantly expanding, encouraging high-tech industries in China such as the lithium-ion battery and fuel cell materials sectors to break through technical barriers and realize rapid development. Overall, there is still a large gap between China's new energy materials sector and levels of development found internationally. The competitiveness of China's new energy materials industry must be strengthened. An independent innovation system with enterprises acting as central entities must be improved. Access to key materials and dependence on imports of high-end materials must be addressed. Therefore, it is imperative to seize opportunities, plan appropriately, and enhance support for the new energy materials industry, which is of great strategic significance for accelerating the transformation of China's economic development, enhancing international competitiveness, and achieving green and low-carbon process for the production of materials.

2 Development of typical key materials for new energy

2.1 Lithium-ion battery materials

At present, most core technologies used in the lithium-ion battery sector have been developed in the European Union, the United States, Japan, or South Korea. Japan was the first to produce highly sophisticated lithium-ion batteries. Japan's Matsushita Electric Co., Ltd. controls the battery supply chain of Tesla Automobile Company; lithium-ion batteries produced by Japan's Nippon Electric Company (NEC) Co., Ltd. and South Korea's LG Chemical Co., Ltd. have good safety records for Nissan LEAF and Chevrolet Volt/Bolt electric vehicles, respectively; Japan's Murata Manufacturing Co., Ltd. is a battery supplier that obtains the China Compulsory Certification; and South Korea's LG Chemical, Samsung SDI, and SK innovation battery companies are the main suppliers of Volkswagen, BMW, and Mercedes Benz, respectively. China has always placed great importance on lithium-ion battery materials research, which were a key focus of the 863 Program of the 1980s. In recent years, with the development of the new energy vehicle industry, research and development (R&D) investment in lithium-ion battery materials has remained high.

Compared to those produced in developed countries, the proportions of high-end new materials in China's lithium-ion batteries are relatively low, their technological levels are unsophisticated, and the added value is low. High-precision automation equipment for high-end materials and batteries still needs to be imported in large quantities. In recent years, with the support and promotion of relevant government departments, and benefiting from rapid proliferation of new energy vehicles and smart phones, China's CATL and BYD have become global suppliers of batteries. Shanghai Shanshan Technology Co., Ltd. and BTR New Materials Group Co., Ltd. have ranked among the top in the world in terms of production capacity for electrode materials. China's production capacity of electrolyte and separator accounts for over 50% of the global total.

The United States, Japan, and South Korea have relatively comprehensive patent coverage in the field of lithium-ion batteries. To a certain extent, patents issues are still a barrier to lithium-ion battery development in China.

2.2 Cathode and anode materials

China's relevant enterprises have a late mover advantage in lithium iron phosphate and low- and medium-nickel ternary cathode materials. Some relevant products have been widely used in China, whereas some have been exported. China is still in a catch-up phase with respect to high-nickel multielement ternary cathode materials, and relevant enterprises are expected to eventually outdo their competitors by solving key problems and upgrading production line.

Market concentration in anode materials is relatively high, and China has a leading international market share. In 2019, Chinese enterprises accounted for 74% of total global shipments of anode materials. BTR New Materials Group Co., Ltd.; Shanghai Shanshan Technology Co., Ltd.; and Jiangxi Zichen Technology Co., Ltd. have been global leaders in research, development, and industrialization of anode materials, to meet the demands of power battery enterprises.

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2.3 Electrolytes

Global electrolyte market share is mainly occupied by Japan's Mitsubishi Chemical Co., Ltd. and Ube Industries, Ltd. and by South Korea's Samsung SDI companies. Each company has a unique additive preparation technology. China still has some import dependence for certain functional additives.

Guangzhou Tinci Materials Technology Co., Ltd.; Shenzhen Capchem Technology Co., Ltd.; Zhangjiagang Guotai Huarong New Chemical Material Co., Ltd.; and Tianjin Jinniu Battery Material Co., Ltd. are global leaders in terms of R&D and industrialization, meeting the electrolyte requirements for China's power battery enterprises. With the increasing market concentration rate of electrolyte and the gradual formation of industry leading clusters, some of the above companies have entered the international mainstream battery enterprise supply chain.

At present, carbonate solvents and lithium hexafluorophosphate are mainly produced in China. Representative enterprises such as Guangzhou Tinci Materials Technology Co., Ltd.; Do-Fluoride Chemicals Co., Ltd.; and Tianjin Jinniu Battery Materials Co., Ltd. engage in large-scale production of lithium hexafluorophosphate electrolytes. Large-scale production of electrolyte functional additives (such as ethylene carbonate, fluoroethylene carbonate, 1,3-propane sulfonic acid lactone, 1,3-propanesulfonic acid lactone, or vinyl sulfate) has also occurred.

2.4 Separator materials for lithium-ion batteries

The best separator material for lithium-ion batteries is produced by Japan's Asahi Chemical Co., Ltd. and Toron Chemical Co., Ltd. China's market share in the field of dry separators has exceeded that of the United States, South Korea, and Japan, and the wet separator field is expanding substantially. Shanghai Energy New Materials Technology Co., Ltd.; Suzhou Jieli New Energy Materials Co., Ltd.; Hebei Gellec New Energy Science and Technology Joint Stock Co., Ltd.; Shenzhen Xingyuan Material Technology Co., Ltd.; and other enterprises have formed a unique industrial development mode to meet China's separator material requirements. However, the raw materials and core equipment required for separator material production are still imported.

2.5 Research on basic materials related to membrane electrodes

The current lack of original innovation in metal bipolar plate technology for fuel cells in China is reflected in the gap between research on basic materials related to membrane electrodes and international levels of development, especially in the area of proton exchange membranes. Global manufacturers of perfluorosulfonic acid membranes are mainly located in the United States, Canada, Japan, or Belgium, among which the Gore Company from the United States is the leading proton exchange membrane supplier. China's Shandong Dongyue Group Company has made rapid progress in proton exchange membrane R&D and industrialization and formed a complete industrial supply chain for fluorosilicone materials. Zhejiang Hancheng Technology Co., Ltd. has mastered key technologies for proton exchange membranes, such as ultrahigh molecular weight polytetrafluoroethylene resin, fluorine-containing proton exchange resin, biaxially stretched film and coating films. The company has secured independent intellectual property rights and started large-scale production of proton exchange resin and membranes. The technical level of membrane electrode production has greatly improved.

2.6 Catalysts

The development of low-platinum or platinum-free high-activity and high-stability oxygen reduction reaction (ORR) catalysts has been the focus of proton exchange membrane fuel cell (PEMFC) development [6–9]. At present, the main suppliers of automotive fuel cell electrocatalysts are the United Kingdom's Johnson Matthey, Japan's TKK, and Germany's BASF. Fuel cell catalysts are still in R&D in China, and two main types of institutions are involved: enterprises such as Sino-Platinum Metals Co., Ltd., which mainly deals with platinum catalysts for automobile exhaust and has jointly developed fuel cell catalysts with the Shanghai Automotive Group, and research institutes executing Pd@Pt/C core shell catalysis such as the Dalian Institute of Chemical Physics and the Chinese Academy of Sciences, which have achieved high levels of oxygen-reducing activity and stability. At present, platinum alloys are a major focus of research for ORR catalysts [10–12].

2.7 Gas diffusion layer substrate

Commercial carbon paper or carbon cloth can be used as the base material for gas diffusion layers. Toray Industrial Inc. of Japan and SGL Carbon of Germany are mature carbon paper or carbon cloth suppliers for gas diffusion layer products. Among these products, the carbon paper produced by Toray Industrial Inc. is characterized by high conductivity, high durability, high gas permeability, and smooth surfaces. Toray occupies a large global market share, with numerous carbon paper-related patents. As there is currently no commercial product in this field in China, the development of independent and secure sources of diffusion layer products is urgently needed. Central South University is continuously conducting research on carbon paper for fuel cells, and Jiangsu Tianniao Company is developing carbon paper from carbon fiber products.

3 Problems in the development of key materials for new energy in China

Lithium-ion batteries are widely used in mobile phones and other portable electronic products, electric vehicles, and power storage fields. These batteries serve the information industry and are an important supporting technology for transportation and power energy revolution. As a core technology of China's new energy materials industry, fuel cells are referenced in the *Action Plan of Energy Technology Revolution and Innovation (2016–2030)*, the *13th Five-Year National Science and Technology Innovation Plan*, and the *Medium- and Long-Term Development Plan of Renewable Energy*. China is heavily involved in new energy materials but is not a leader in this field. Problems related to weak self-sufficiency, less high-end material domestic suppliers, and low resource utilization capacity seriously restrict the sustainable development of new energy materials in China.

3.1 Some basic raw materials rely on imports, which seriously threatens the safety of the key strategic materials industry supply chain

The design and production of some functional additives for lithium-ion battery electrolytes depends on imports to a certain extent, particularly in the fields of high-performance membrane materials, basic nonwoven fabrics, polysulfone, interfacial polymerization monomers, and other raw materials. Core components of fuel cell membrane electrodes such as proton exchange membranes, resin solutions, catalysts, and carbon paper are largely imported. The large-scale production of ultrathin enhanced proton exchange membranes with independent intellectual property rights in China is in an initial stage. Mass production capacity of electrocatalysts has improved in China, but there remain large gaps in performance and durability relative to other countries. Large-scale use of carbon paper diffusion layers relies on imports, while suppliers of carbon paper are constantly increasing prices and greatly reducing exports, threatening the safety of China's key strategic materials industry supply chain.

3.2 Self-sufficiency in high-end products is low, and domestic users of high-end materials is insufficient

Key material technologies of lithium-ion batteries produced in China still lag behind those of foreign countries, and some high-end materials still rely on imports. A lack of technological innovation and independent new products, slow product upgrades, and shortfalls of relevant patents and core technologies have hindered China's participation in the international market. A shortage of key materials such as Co, Li, graphite, and other resources has also led to increasing prices and erratic supply.

There is still a large gap between China's automotive fuel cell technologies and those of other countries in terms of stack performance, life, and costs. At present, foreign high-end fuel cell sales are prohibited in China, so independent design and development is urgently needed. However, core materials and components required for high-end product R&D still rely on imports of materials such as proton exchange membranes. China is implementing major special research projects for such high-end basic materials. Self-sufficiency and support for high-end products is expected to greatly improve by the end of the 14th Five-Year Plan.

3.3 Innovation is insufficient, and an industry–university–research–application cooperative platform is underdeveloped

China's basic research on new energy materials has been limited and shows many weaknesses in favoring applications over foundations, imitation over original innovation, and seriously restricting technical improvement in

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China's new energy materials industry. In addition, there is currently no industry–university–research–application cooperative platform for innovation and basic research, and a large number of innovation achievements remain at the laboratory research stage. There is no efficient R&D platform for carrying out pilot process validation and scale-up on basic research results, hindering the rapid transformation and industrial application of scientific research.

3.4 Insufficient investment in basic innovation and R&D

Core technology and manufacturing equipment for new energy materials rely on foreign suppliers, and the industry remains in the middle and low reaches of the value chain in China. The allocation of R&D investment is imbalanced and focused on applied technology, with low investment in basic research, leading to a lack of stamina in addressing key technologies. Limited connections between basic research and industrial production constrains the transformation of research outcomes, resulting in a lack of innovation.

4 R&D in new materials and development trend of the industry

4.1 The industry's monopoly has further intensified, and the control of key materials has become the focus of competition

The enterprises continue to expand into the field of new energy materials, especially those that play a dominant role in key strategic material products with high added value. By dominating technologies and markets, such enterprises can implement product blockades or dumping and restrain economic growth and the implementation of major projects in competitive countries. Progress in material technologies forms the basis for power battery improvements. As an example, the ternary cathode battery is currently being transformed from a low-nickel to a high-nickel model. A small number of enterprises in the United States monopolize the technical patents for high-capacity lithium-rich and low-cobalt/cobalt-free cathode materials. A few enterprises in Germany, Japan, and South Korea occupy advantageous positions in high-nickel and low-cobalt ternary battery materials. Japan's Shin-Etsu Chemical Co., Ltd. and the United States' 3M have key patents for silicon-based anode materials. The production capacity of cathode and anode and other battery raw materials in China comes first in the world, but the country's core patents are still lacking.

The performance and cost of membrane electrodes (including catalysts, membranes, and carbon paper) have created a bottleneck in large-scale commercialization of fuel cells. The platinum catalyst produced by Tanaka Precious Metal Group in Japan ranks first in international market share, and Gore leads in global proton exchange membrane supplies. Carbon paper produced by Toray Industrial Inc., SGL Carbon, and Ballard Power of Canada constitute the main imported products used in China's fuel cell sector. The supply chain for carbon paper has been interrupted, posing a serious threat to the market security of fuel cells in China.

4.2 Green, low-carbon development has become an important trend in the development of new energy materials

The new energy materials industry and its applications, characterized by energy conservation, environmental protection, and green, low-carbon development, have expanded rapidly. With the continuous development of lithium-ion battery and fuel cell technologies, new energy vehicles have gradually entered thousands of households. Meanwhile, electric and intelligent vehicles complement each other, spurring profound changes in the automotive and energy industries. The next 10 years will constitute a golden age for mainstream hybrid and fully electric vehicle markets and for rapid development of fuel cell vehicle technology, promoting the development of onboard hydrogen production systems for fuel cells. High-efficiency, clean, and economical fuel cells will be central to the future development of world powers. With the gradual improvement of supporting technologies, fuel cell vehicles are expected to become mainstream new energy vehicles in 15–20 years, especially in the heavy truck and coach market, which will usher in unprecedented development opportunities for reforming high-temperature catalytic materials for hydrogen production.

4.3 Accelerating development of high-performance, cutting-edge new energy materials

Major original achievements reflect the power of science and technology. Continuous scientific and technological innovation forms the cornerstone of maintaining the status of a powerful country. With a series of high-tech breakthroughs, key materials of lithium-ion batteries and hydrogen fuel cells continue to develop higher precision and performance.

Under the joint actions of technological progress and industrial development, battery systems have significantly improved and production costs decreased. In recent years, China's power battery technologies have developed in leaps and bounds. Large-scale production has been achieved; the specific energy of soft-pack batteries with high-nickel ternary materials has reached 288 Wh/kg, and the specific energy of passenger car battery systems is concentrated in the range 140–160 Wh/kg, which is generally higher than other international products.

The performance of key materials, core components, stacks, and fuel cell systems has rapidly improved. Alloying and morphology control technologies are widely used for catalysis in laboratories. Catalyst performance has exceeded technical indicators set by the United States Department of Energy (USDOE) in 2020. Gore has prepared ultrathin reinforced proton exchange membranes from perfluorosulfonic acid resin, reducing surface resistance and improving the specific power of fuel cells. Laboratory research has achieved the platinum consumption index (0.125 mg/cm^2) for membrane electrodes set by USDOE in 2020. At present, the platinum loading capacity of the best commercial membrane electrode for vehicles is still as high as 0.35–0.4 mg/cm^2.

4.4 With the continuous expansion of industrial scale, new energy materials have become an engine of economic growth

Continuous improvement in basic and application research capabilities has led to a series of key energy material technology innovations. China has become a major international producer of lithium-ion battery materials, and many provinces and cities have introduced development specifications for hydrogen energy and fuel cells.

New energy vehicle development is a major strategic measure for ensuring China's energy security and reducing vehicle pollution emissions. In 2019, China's new energy vehicle sales exceeded 1.2 million, ranking first in the world. These sales are expected to reach 15 million in 2030. Lithium-ion batteries for new energy vehicles provide key support for rapid development and energy security in China. PEMFCs have broad applications in transportation and in fixed power stations owing to their high power density and rapid initiation at room temperature.

5 Development path of key materials for new energy in China

5.1 Development ideas

In this paper, the future development of key materials is described with reference to lithium-ion batteries and fuel cells in China.

Technical research, development, testing, application verification, and analysis for lithium-ion power battery materials and equipment should be supported, China must upgrade the lithium-ion battery industry and reduce costs, continuously support innovation and technical development, and achieve higher specific energy levels. We must promote industrial improvements (e.g., by developing advanced equipment, strengthening market share, and implementing advanced management) and product upgrades to maintain rapid development of the domestic market under the support of national new energy vehicle policies. We must prioritize and promote formation and development of large-scale enterprises (or enterprise consortia); promote innovative technologies; and cultivate products, well-known brands, and high-end talent teams to consolidate a strong industry foundation.

China must continue to improve fuel cell technology. We must also encourage the development and application of low-cost and small PEMFCs. We must expand small fuel cell system applications, promote the demonstration operation of fuel cells for electric vehicles, and form a complete industrial supply chain.

5.2 Development goals and key tasks

5.2.1 For 2025

(1) Lithium-ion batteries

The development goals are as follows: solid-liquid hybrid lithium-ion batteries with specific energy ≥400 Wh/kg and cycles ≥1000 times for comprehensive applications in new energy power systems; lithium anode secondary batteries with specific energy ≥500 Wh/kg; and all solid-state lithium batteries with specific energy ≥400 Wh/kg and

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cycles ≥500 times. Annual production capacities will be as follows: cathode materials 2×10^6 t, anode materials 1×10^6 t, separators 1.5×10^{10} m^2, and electrolytes 6×10^5 t.

Key tasks include the following: Focus on high-nickel/low-cobalt or cobalt-free ternary cathode materials, high-voltage nickel manganese spinel cathode materials, lithium-rich manganese-based cathode materials, carbon/alloy and other high-capacity anodes materials. Pursue R&D on ceramic-coated and high-pressure-resistant separators, flame-retardant and pressure-resistant electrolytes. Develop high-energy-density single-cell batteries based on ternary/high-voltage/lithium-rich cathode materials and high capacity carbon/alloy anode materials. Develop model-based electrode/battery designs to improve power and energy density, environmental adaptability. Develop high safety separator, electrolyte and high-stability and low-resistance electrode/electrolyte interface technologies to improve battery performance, life, and costs. Promote local sources of key materials and swiftly upgrade power battery scale manufacturing and quality assurance technology. Advance design principles and material systems for solid-state lithium batteries, clarify dynamic characteristics of the cycle process, and promote new energy vehicle applications. Research recycling technologies for lithium-ion batteries to reduce whole life cycle costs, establish green life cycle design–optimization–evaluation systems, and enhance material sustainability.

(2) Fuel cells

Development goals for 2025 include the standardization, popularization, and application of on-site hydrogen production and storage for refueling stations; development of key fuel cell technologies; and establishment of an industrial supply chain for materials, components, and systems. By 2025, the production capacity of Pt-based electrocatalysts will reach 3 t/a, meeting the requirements of 100 000 vehicle PEMFC systems. Annual production capacities will be as follows: acid ion exchange membranes 2×10^6 m^2, carbon paper 4×10^6 m^2, and membrane electrodes 2×10^6 m^2.

Key development tasks include the following: Focus on developing low-platinum fuel cells, ultrathin acid ion exchange membranes, high-performance carbon paper, inexpensive metal bipolar plates, and high-performance long-life membrane electrodes. For basic materials, innovate theories of catalysis, shifting focus on alloy to core shell and then to single-atom catalysts, to continuously improve the effective use rate of platinum and reduce platinum load. Conduct in-depth research on the preparation and increased production of ultrathin composite membranes, synthesis of base membranes, and molding techniques for ultrathin composite membranes. Study carbon paper preparation methods and quality control using the comprehensive advantages of interdisciplinary technologies. Develop a new preparation process, and scale-up production, for thin-layer ordered high-performance membrane electrodes based on electrostatic spraying, spinning, or other methods. Improve fuel cell technologies and equipment throughout the industrial supply chain with breakthroughs in core materials, including air compressors, reflux pumps, advanced controller design and integration, lightweight systems, seismic resistance, and low-temperature environments. Integrate design of auxiliary systems and fuel cell stacks; reduce costs for key materials, components, and systems; increase service life; and strengthen the durability, reliability, and adaptability of systems.

5.2.2 For 2035

(1) Lithium-ion batteries

Development goals for 2035 are as follows: lithium secondary batteries with specific energy ≥500 Wh/kg and cycles ≥1500 times for scale applications in new energy vehicles and special fields; solid-state lithium batteries with specific energy of ≥600 Wh/kg and cycles ≥1000 times for a mature, complete industrial supply chain; and new batteries with specific energy of ≥800 Wh/kg and cycles ≥100 times. Annual production capacities will be as follows: cathode materials 1×10^7 t, anode materials 3×10^6 t, separators 5×10^{10} m^2, and electrolytes 1.2×10^6 t.

Key tasks include the following: Improve preparation processes for lithium iron phosphate, lithium manganese oxide, and ternary cathode materials; and hard carbon, silicon-based, and other anode materials for continued industrialization of electric vehicles. Develop key technologies such as functional electrolytes and high-safety separators and support technical progress in lithium-ion battery materials. Develop high-quality in situ characterization measurements, nondestructive testing, three-dimensional imaging, and high-speed detection technologies. Create an R&D and service platform for power battery technologies and equipment and organize the whole industry to address key problems. Establish power battery manufacturing processes, equipment, and standards suited to the comparative advantages of China's manufacturing industry and use the Internet, big data, and artificial intelligence to solve problems of quality, efficiency, and cost. Leverage academic institutions for in-depth basic and manufacturing technology R&D, focused on high-capacity lithium-ion anode and cathode materials and new lithium polymer, lithium sulfur, lithium air, sodium air, and solid-state battery systems to produce high-value patents in China for next-generation batteries and materials.

(2) Fuel cells

Development goals for 2035 are as follows: integration of large-scale hydrogen production, storage, transportation, and use; standardization and application of on-site hydrogen storage and production in hydrogenation stations; independent mastery of fuel cell core technologies; establishment of a complete fuel cell industrial supply chain; widespread application of hydrogen energy and fuel cells; and creation of a market value of more than 1 trillion RMB for hydrogen energy vehicles (10%–15% of motor vehicles and more than 10% of energy demand). Low-platinum catalysts should be able to meet the demand of 5 million fuel cell systems, with a capacity of 50 t/a, and nonplatinum catalysts will be in field testing. Ion exchange membranes will meet the needs of 5 million fuel cell systems with annual production capacity of 7.5×10^7 m^2.

Key tasks include the following: Maintain China's international advantages in low-cost alkaline membrane fuel cell research. Focus on new, nonnoble metal catalysts with high activity density and long service life. Develop catalytic theories based on transition metal Fe, Co, and Ni-doped carbon catalysts with high activity density, and accelerate production and sales. Continue innovation in theory, design, and processes of basic ion exchange membranes and develop high-performing and sustainable long-life alkaline membranes. Develop environmental air and water management controls for basic acid membrane and alkaline membrane electrode production, to lay a foundation for development of next-generation, high-performance, long-life fuel cells with low-cost materials.

6 Countermeasures and suggestions

6.1 Top-level planning and increased policy support

Improve design and planning, strengthen scientific and technological support, develop relevant system standards and norms, build capacity, and realize strategic coordinated development. Expand the role of enterprises and scientific research institutes, establish benign cooperation to foster innovation, promote research results for improving production technologies, and strengthen the patent landscape in core technologies. Establish product standards, standardize the market, and create a strong development environment. Increase national funding for scientific research projects, support new energy material technologies, focus on the weak links of key technologies, introduce relevant policies and measures, encourage increased R&D investment and face international market competition.

6.2 Innovation-driven strategies and superior enterprise cultivation

Following are some measures to drive innovation and cultivate business: implement innovative strategies; concentrate on advantageous resources; make concerted efforts to address key problems; make the material enterprises work; increase technological R&D for advanced materials; improve material performance; invest in materials and equipment; ensure the accuracy, consistency, and reliability of production; and reduce costs and strengthen the global competitive advantage of the industry.

At the same time, we must accelerate industrial structure realignment, organizational development, and technical optimization for new energy materials; cultivate leading new energy material enterprises with strong technologies; and continuously promote the combination of industry with funding to achieve developmental advances.

6.3 Build a demonstration platform through coordination and linkages

To realize these ambitious goals, the following actions are necessary: strengthen financial support for scientific and technological innovation; accelerate construction of innovation centers through various channels, such as industrial investment funds; encourage problem solving in cutting-edge and common core technologies through national science and technology plans (special projects, funds, etc.); and strengthening international technical cooperation.

In addition, we must construct demonstration production and application platforms in key national fields; promote

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industrial transformation and upgrades; focus on improved application and development of software and hardware; innovate common application technologies used in key fields; and realize collaboration between new energy material and terminal product design, system verification, and applications.

6.4 Use talent flexibly and assemble strong talent teams

With the end goals in mind, we must pool high-end industry talent, build talented teams, improve training, encourage enterprises to increase investment, and implement a policy of international talent recruitment and exchange. Through the flexible use of talent, we can concentrate innovation power, stimulate talent development, improve international competitiveness, and gather international talent and wisdom on a large scale.

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