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# Current Status and Prospects of High-Performance Synthetic Rubber in China

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**Abstract:** Synthetic rubber materials are widely used in industry, national defense, transportation, and daily life. High-performance and functional synthetic rubber are key advanced base materials necessary for the development of the new era. Based on industrial survey data, we systematically summarize the development status of high-performance synthetic rubber materials in China, analyze the main problems in production, research and development, application, and other aspects, and propose development directions for high-performance synthetic rubber materials in China. We suggest that China focuses on the development of high-performance and functional synthetic rubber, such as functionalized solution-polymerized styrene-butadiene rubber, neodymium-based cis-1,4-polybutadiene rubber, branched butyl rubber, and functionalized thermoplastic elastomers, as well as special rubber materials, such as hydrogenated nitrile rubber, thermoplastic vulcanized rubber, high-performance silicone rubber, and fluoroether rubber, to achieve high-end materials, green processes, and intelligent production.
**Keywords:** synthetic rubber; thermoplastic elastomer; special rubber material; development strategy

## 1 Introduction

Synthetic rubber is one of the three major synthetic materials that is not only a petrochemical product closely associated with our daily lives, but also an important national strategic resource. It is widely used in industry, national defense, transportation, and daily life. Synthetic rubber can be categorized broadly into general and special rubber. General synthetic rubber refers to raw rubber used to produce tires and other commodities, including styrene-butadiene rubber (SBR), butadiene rubber (BR), butyl rubber/halobutyl rubber (IIR/HIIR), ethylene propylene diene monomer rubber (EPDM), nitrile rubber (NBR), isoprene rubber (IR), chloroprene rubber (CR), and styrenic block copolymers (SBCs) [1]. High-performance synthetic rubber refers to high-end and functional general synthetic rubber and special synthetic rubber, which are key advanced chemical basic materials necessary for the development of the new era [2].

After more than 40 years of rapid development, China's high-performance synthetic rubber material industry has developed rapidly from small-scale to large-scale. High-performance and functional general synthetic rubbers, such as functionalized solution-polymerized styrene-butadiene rubber (SSBR), neodymium-based cis-1,4-polybutadiene rubber, star-branched halogenated butyl rubber, and functionalized thermoplastic elastomers, as well as special rubber products, such as hydrogenated nitrile rubber (HNBR), thermoplastic vulcanized rubber (TPV), high-performance silicone rubber, and fluoroether rubber, have been successfully developed. China's synthetic rubber industry is gradually moving toward the development of high-end, green, and intelligent

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production.

## 2 Characteristics and application fields of high-performance synthetic rubber materials

High-end and functional general synthetic rubber primarily refer to functionalized SSBR, neodymium cis-1,4-polybutadiene rubber, and star-branched halogenated butyl rubber, which are applied to the tread, sidewall, and inner liner of high-performance tires to significantly improve tire performance, as well as polar styrene-butadiene thermoplastic elastomer (SBS), styrene-isoprene block copolymer (SIS), hydrogenated styrene-butadiene block copolymer (SEBS), hydrogenated styrene-isoprene copolymer (SEPS) thermoplastic elastomer, long-chain branched ethylene-propylene rubber, and functionalized high-impact styrene-butadiene resin, which are used in the fields of sealing and waterproofing under severe conditions, adhesives, polymer modification, optical cables, etc. Special synthetic rubber materials are rubber materials that are different from general rubber materials and exhibit special properties such as high- and low-temperature resistance, aging resistance, ablation resistance, and chemical resistance, primarily including HNBR, TPV, silicone rubber, and fluororubber. The distinct properties of special synthetic rubber materials render them key materials necessary for the development of national major strategies and emerging fields such as aerospace, national defense and military, electronic information, energy, environment, and ocean [3].

Currently and in the future, advanced general rubber and special rubber materials urgently required for national defense and national economic development primarily include the following.

SSBR, which differs from traditional emulsion-polymerized styrene-butadiene rubber (ESBR), is a butadiene-styrene copolymer rubber prepared via lithium anionic solution polymerization. Because of its designable structure and adjustable performance, it is an ideal rubber for manufacturing tire treads. As a type of high-performance synthetic rubber, SSBR offers better rolling resistance and wet skid resistance than ESBR, and it is recognized as a necessary rubber component in the rubber composite system of green tires.

HNBR is a type of high-saturation rubber material prepared by the selective hydrogenation of the butadiene unit on the NBR chain to improve the heat resistance and aging resistance of NBR. Its main feature is that it can be used for a long time at 150 °C, and it can maintain high physical and mechanical properties at high temperatures. Furthermore, it can satisfy the special requirements of high-temperature and chemical resistance of materials in automobile, aerospace, oil fields, and other fields; hence, it is widely used. For example, it can be used as an automobile oil seal, fuel system component, automobile transmission belt, piston for drilling holding boxes and mud, rubber rollers for printing and textiles, seals for aerospace, damping materials, etc.

IIR/HIIR is a linear polymer material synthesized by the low-temperature cationic polymerization of isobutylene and a small amount of isoprene. Butyl rubber is the best air-tight rubber and is widely used in tire inner tubes, vulcanized capsules, medical rubber stoppers, and rubber hoses. Halogenated butyl rubber, which includes brominated butyl rubber and chlorinated butyl rubber, is a halogenated modified butyl rubber product. Halogenated butyl rubber retains the original properties of butyl rubber, improves the vulcanization latitude of products, and can be co-vulcanized with other types of general rubber to yield tubeless tires with better heat resistance.

Hydrogenated styrene thermoplastic elastomers include thermoplastic elastomers SBS and SIS. They change most unsaturated double bonds into saturated bonds after hydrogenation. Furthermore, they not only retain their excellent elasticity, but also significantly improve their heat resistance, light resistance, and thermal oxygen resistance. Hydrogenated SBS (SEBS) can be widely used to produce high-grade elastomers, resin modification, adhesives, lubricating oil tackifiers, fillers, and sheathing materials for wires and cables. With the increase in bicycle sharing, SEBS has become a popular topic in the production of non-pneumatic tires. Hydrogenated SIS (SEPS) is primarily used in lubricating oil viscosity enhancement, transparent elastomer and film production, lubricating grease, optical cable sealing ointment, cosmetics, and coated leather [4].

IR, which is synthesized from isoprene and resembles natural rubber the most in terms of structure, is the best substitute for natural rubber and can be used in tires and other industries.

TPV, also known as dynamic vulcanized thermoplastic elastomer, is a thermoplastic elastomer material prepared by vulcanizing the rubber phase in the melt blending process of the plastic phase (such as polypropylene) and rubber phase (such as EPDM), as well as a granular vulcanized rubber phase existing stably in the plastic phase in a microzone phase state. It exhibits both the high elasticity of traditional rubber and the thermoplastic processability of plastic materials, as well as excellent properties such as low density, recyclability, easy processing, low energy consumption, and long-term aging resistance.

Silicone rubber is a type of special synthetic rubber made from linear polysiloxane mixed with a reinforcing

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filler, a functional filler, and an auxiliary agent; it is vulcanized under heating and pressure to become an elastomer with a network structure. It exhibits excellent high-and low-temperature resistance, weather resistance, ozone resistance, arc resistance, electrical insulation, moisture resistance, high air permeability, and physiological inertia. It has been widely used in modern industries, electronics and electrical, automobiles, construction, medical treatment, personal care, and other fields, and has become an indispensable advanced high-performance material in aerospace, national defense and military, intelligent manufacturing, and other fields.

Fluororubber is a rubber material containing fluorine atoms on the carbon atoms of the main chain or side chain, and its special properties are determined by the structural characteristics of the fluorine atoms. Fluororubber can be used at 250 °C for a long time, and the temperature can reach 300 °C, whereas the temperature of traditional EPDM and butyl rubber can only reach 150 °C. In addition to high-temperature resistance, fluororubberexhibits excellent oil resistance, chemical medium resistance, as well as acid and alkali resistance, and its comprehensive performance is the best among all rubber elastomer materials. It is primarily used in special applications such as oil-resistant seals and oil-resistant pipelines for vehicles such as rockets, missiles, airplanes, ships, and automobiles; additionally, it is an indispensable key material for the national economy, national defense, and military industries.

## 3 Development status of high-performance synthetic rubber materials industry in China and abroad

### 3.1 Synthetic rubber

In 2017, the global synthetic rubber production capacity exceeded 2 × $10^7$ t/a. In 2018, the global total production capacity was approximately 2.042 × $10^7$ t/a, which is primarily distributed in Asia, North America, and Europe. China is the largest producing and consuming country, with an annual production capacity of 5.93 × $10^6$ t, constituting 29% of the global total production capacity [5,6] (Fig. 1).

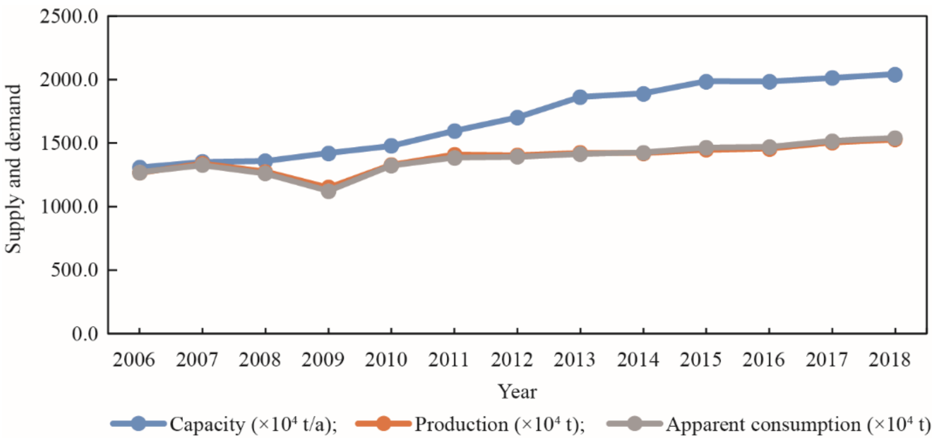


**Fig. 1.** Worldwide supply and demand of synthetic rubber in recent years [5,6].

In 2020, the world synthetic rubber production capacity will reach 2.2 × $10^7$ t/a. Among all rubber types, SSBR exhibited the largest increase in production capacity, followed by IIR and EPDM (Fig. 2) [6].

In 2017, the global production of synthetic rubber was 1.505 × $10^7$ t, i.e., a year-on-year increase of 1.4%, and the consumption of synthetic rubber was 1.519 × $10^7$ t, i.e., a 2.4% year-on-year increase. In 2018, the total production capacity of synthetic rubber worldwide was 2.042 × $10^7$ t, the output was 1.533 × $10^7$ t, the utilization rate of production capacity was approximately 75%, indicating an overcapacity. By 2025, the output and consumption will be approximately 2 × $10^7$ t each.

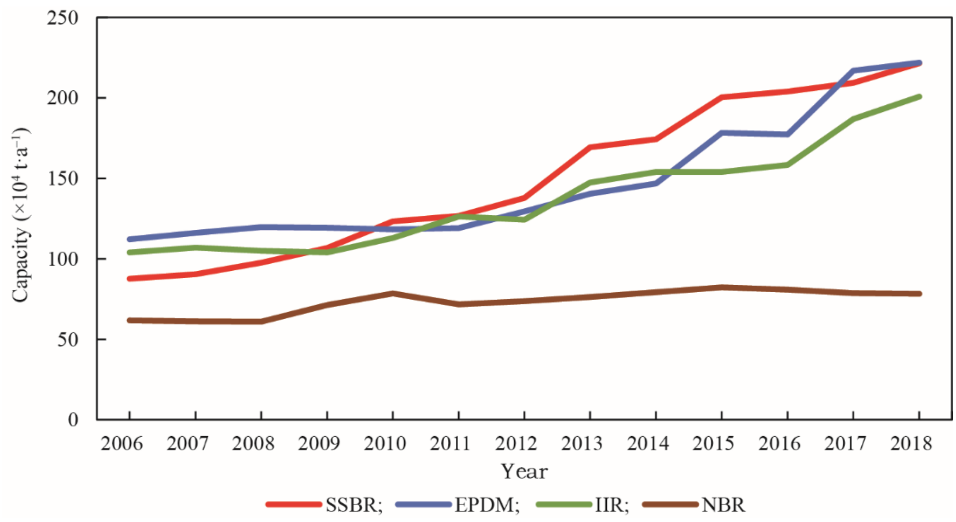


**Fig. 2.** Changes in production capacity of major rubber varieties worldwide in recent decade [5,6].

Fifty synthetic rubber manufacturers are available in China, affording a total capacity of 5.93 × $10^6$ t/a. China has formed a four-point pattern comprising Sinopec (29%), PetroChina (20%), private enterprises (29%), and Taiwan-funded and foreign-funded enterprises (22%). Sinopec offers advantages in terms of BR and SBCs; PetroChina, ESBR; private enterprises (32 in total), IIR and IR; and Taiwan-funded and foreign-funded enterprises, EPDM and NBR.

In 2017, China's general synthetic rubber output was 3.557 × $10^6$ t, export volume was 1.41 × $10^5$ t, import volume was 1.365 × $10^6$ t, and apparent consumption was 4.781 × $10^6$ t, exhibiting record high numbers. Details of the supply and demand of the major rubber varieties are shown in Table 1. In 2018, the output was 3.67 × $10^6$ t, and the capacity utilization rate was 62%.

In 2020, the demand for synthetic rubber in China will exceed 4.8 × $10^6$ t/a. The transformation of the national economic structure not only requires the adjustment of product structure for the synthetic rubber business, but also offers rare opportunities for the development of the advanced basic material business.

**Table 1.** Supply and demand of synthetic rubber in mainland China in 2017[7]. (unit: 1000 t)

| Synthetic rubber | Production | Export volume | Import volume | Apparent consumption |
|---|---|---|---|---|
| ESBR | 1016 | 27 | 379 | 1368 |
| SSBR | 62 | 1 | 32 | 93 |
| BR | 965 | 42 | 268 | 1191 |
| EPDM | 183 | 13 | 212 | 381 |
| HIIR | 84 | 6 | 211 | 290 |
| NBR | 161 | 7 | 91 | 245 |
| IIR | 62 | 11 | 64 | 115 |
| IR | 71 | 2 | 44 | 113 |
| CR | 29 | 5 | 21 | 46 |
| SBCs | 924 | 27 | 43 | 940 |
| Total | 3557 | 141 | 1365 | 4781 |

### 3.2 Fluororubber

The main varieties of fluorine rubber are conventional binary fluorine, ternary fluorine, perfluoroether, carboxyl nitroso fluorine, fluorinated phosphazene, low-temperature resistant fluorine, and fluorosilicone rubbers. The main fluorine rubber manufacturers and brands are listed in Table 2.

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**Table 2**. Main manufacturers and grades of fluororubber [8].

| Comonomer | Manufacturer | Typical commodity grades | Country | Major application units or fields |
|---|---|---|---|---|
| Vinylidene fluoride–hexafluoropropylene | Dupont Corp.<br>3M Company<br>Daikin Industries Co., Ltd.<br>Solway Group | VitonA and E<br>Fluorel2140, 2141<br>Daiel G501, G801<br>Techno flonsL, SH, NL<br>CKΦ-26<br>F26 series | USA<br>USA<br>Japan<br>Italy<br>Russia<br>China | Shanghai Daofu Industrial Co., Ltd., Shanghai Chuangqite Rubber Products Co., Ltd., Chengdu Daohong Industrial Co., Ltd., and other military industry units |
| Vinylidene fluoride–hexafluoropropylene–tetrafluoroethylene | Dupont Corp.<br>3M Company<br>Daikin industries Co., Ltd.<br>Solway Group | VitonB<br>Fluorel2145, 2230<br>Daiel G601, G701<br>Techno flonsT, TN, TH<br>F246 series | USA<br>USA<br>Japan<br>Italy<br>China | Shanghai Daofu Industrial Co., Ltd., Shanghai Chuangqite Rubber Products Co., Ltd., Chengdu Daohong Industrial Co., Ltd., Anhui Zhongding Holding (Group) Co., Ltd., and other military industry units |
| Vinylidene fluoride–hexafluoropropylene–tetrafluoroethylene–vulcanizable monomer | Dupont Corp.<br>3M Company<br>Daikin Industries Co., Ltd.<br>Solway Group | VitonGH, GF<br>Fluorel2690, 2460<br>DaieG901, G902<br>TechnoP459,P959<br>FKM50XPL, FKM246-XP | USA<br>USA<br>Japan<br>Italy<br>China | Shanghai Daofu Industrial Co., Ltd., Shanghai Chuangqite Rubber Products Co., Ltd., Chengdu Daohong Industrial Co., Ltd., and other military industry units |
| Vinylidene fluoride-chlorotrifluoroethylene | 3M Company | Kel-F5500, 3700<br>FKM2311, 2301 | USA<br>China | Primarily domestic military industry units |
| Tetrafluoroethylene-propylene | Asahi Glass Company | Aflas100, 150, TP-1 | Japan | Application field of special requirement |

As a special rubber, fluororubber is used as a sealing material under various harsh conditions because of its distinct properties afforded by fluorine atoms. Currently, China's conventional fluorourubber has been industrialized; its industrial scale is leading internationally, and its performance is comparable to that of the international market. Special fluororubbers have been gradually localized, and the types of products have gradually improved. In 2017, the global total production capacity of fluororubber was approximately $4.77 \times 10^4$ t/a, of which China exceeded $2.34 \times 10^4$ t/a, constituting approximately 50% of the global total production capacity. The main fluorine rubber manufacturers worldwide in recent years are listed in Table 3.

**Table 3**. Production capacity and technical characteristics of major fluorine rubber manufacturers [8].

| Enterprise name | Production capacity ($t \cdot a^{-1}$) | Location of device | Technology |
|---|---|---|---|
| Dupont Corp. | 4500 | United States (Decpwater, New Jersey) | Advanced technology, mature technology, complete product range, and advanced technology rank first in the world |
| 3M Company | 2500 | United States (Decatur, Alabama) | Advanced technology, mature technology, and complete product range |
| Solway Group | 1500 | United States (Thorofare, New Jersey) | Advanced technology, mature technology, and complete product range |
| 3M Company | 2800 | Belgium (Antwerp) | Production began in 1986, with advanced technology and mature technology |
| Daikin Industries Co., Ltd. | 1000 | France (Pierre–Benite) | Production began in 2004, with advanced technology and mature technology |
| Solway Group | 3500 | Italy (Spinetta) | Production began in 1986 (formerly Ausimont Company), with advanced technology, mature technology, and complete product range |
| Dupont Corp. | 3000 | The Netherlands (Dordrecht) | Production began in 1986, with advanced technology, mature technology, and complete product range |
| Asahi Glass Company | 1500 | Japan (Chiba Prefecture) | Tetrafluoroethylene-propylene rubber, with advanced technology, ranks first in the world |
| Daikin Industries Co., Ltd. | 3000 | Japan (Osaka) | Advanced technology, mature technology, and complete product range |
| Total | 23300 | | |

In recent years, newly built or planned fluorourubber projects have primarily been concentrated in China. Foreign companies such as Daikin Industry Co., Ltd. have built 3200 t/a devices in Changshu [8], Solvay Special Polymer (Changshu) Co., Ltd. built a 3000 t/a plant in Changshu, and Chemours Company under DuPont cooperated with Zhonghao Chenguang Chemical Research Institute Co., Ltd. Plans to build a 5500 t/a plant. Currently, the Zhejiang Juhua Group and other companies are planning to build a 3000 t/a high-performance fluorourubber plant.

Since 2000, owing to the rapid development of the national economy, the demand for fluororubbers in various countries has increased significantly. The global demand was approximately $3.35 \times 10^4$ t in 2017 and will reach $4 \times 10^4$ t in 2020. In 2017, the demand for fluorourubber in China was approximately $1 \times 10^4$ t. It is predicted that the demand for fluorourubber in China will reach $1.5 \times 10^4$ t during the 14th Five-Year Plan period. With the further acceleration of China's national defense modernization construction, the research and development of new-generation combat vehicles and fighters has promoted the application of various new fuels and propellants. The application field of fluororubber in the national defense military industry has progressed from seals and electrical line sheaths to the main molding materials of various new fuel oil pipelines, and its market potential is considerable. Currently, owing to the gap in the industrial scale, variety structure, and processing capacity, domestic fluorine rubber production enterprises cannot fully satisfy the requirements of the military industry.

### 3.3 Silicone rubber

Silicone is a new material with high performance, and the global demand for silicone compound growth rate is approximately 5%. Major silicone producers in the world include the Dow Group of the United States, Momentive Performance Materials Group of the United States, Shin–Etsu Group of Japan, Wacker International Group Co., Ltd., and China Bluestar (Group) Co., Ltd. in Germany. The production facilities are primarily distributed in China, the United States, Germany, Britain, Japan, France, and South Korea. [9].

Since 2000, as China becomes the world manufacturing center, the silicone industry has progressed significantly, and China has become an important silicone production and sales country in the world. By the end of 2017, 13 methyl siloxane monomer production enterprises were available in mainland China, with a total polysiloxane production capacity of $1.38 \times 10^6$ t/a, output of $1.02 \times 10^6$ t and apparent consumption of $9.7 \times 10^5$ t [10]. In 2018, the apparent consumption exceeded $1 \times 10^6$ t for the first time, reaching a record $1.04 \times 10^6$ t, with a year-on-year increase of 7.4%, among which the largest consumption proportion was in the fields of construction, electronic and electrical, medical care, and personal care. In the future, in addition to the steady growth of traditional application fields, cutting-edge application fields such as new energy, artificial intelligence, fifth generation mobile communication technology, and high-end medical care will propel China's silicone rubber industry toward high-quality development.

During the 13th Five-Year Plan period, China's silicone rubber industry has progress significantly in terms of industrial development, structural adjustment, technological progress, energy conservation and emission reduction. However, China remains lagging in terms of development quality, technical level, and application development. The small-scale, low concentration, and low automation of silicone rubber production has not changed fundamentally; however, the safety, environmental protection, and automatic production technology must be further improved.

## 4 Main problems encountered in development of high-performance synthetic rubber materials in China

### 4.1 Industry is significant but weak, and competitiveness of enterprises is weak

Since the 21st century, the domestic synthetic rubber industry has progressed rapidly owing to the rapid development of the national economy. During 10 years of the 11th Five-Year Plan and 12th Five-Year Plan, state-owned, private, and Taiwan/foreign-funded enterprises were keen to invest in the synthetic rubber industry, resulting in a significant increase in domestic production capacity that exceeded the increase in domestic synthetic rubber production and consumption in the same period. However, since 2008, indications of surplus were observed; in fact, the surplus has gradually expanded since 2012. Owing to the market price and production cost as well as the impact of imported products in 2017, the domestic synthetic rubber output totaled $3.557 \times 10^6$ t, and the effective capacity utilization rate was 64.0%, which was lower than the average capacity utilization rate of synthetic rubber plants in the world by 8.8%. Adjusting the product structure and improving market

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competitiveness has become primary issues in the synthetic rubber industry [7].

### 4.2 Insufficient supply of mid-to-high-end brands; shortage coexists with structural surplus

After 70 years of development, China has successfully produced all types of general synthetic rubber, and its production capacity, output, and consumption rank first in the world. However, serious problems exist, such as product homogenization, low proportion of high value-added products, and reliance on imports for special high-performance products. Only the IR industrial plant has transcended the traditional technical paradigm, adopted a rare-earth catalytic system, and realized the industrialization of IR through a new technical route. Nevertheless, problems such as unstable product quality exist. High-end SSBR and brominated butyl rubber are primarily imported, and China is currently unable to produce high Mooney viscosity ethylene-propylene rubber. More than 20 brands of NBR exist, among which ultrahigh acrylonitrile NBR, carboxyl nitrile butadiene rubber, hydrogenated nitrile butadiene rubber, and powdered nitrile butadiene rubber primarily rely on imports. However, the variety and application of domestic fluororubbers in China are still lacking; in particular, backward processing and application technologies, such as automobile crankshaft oil seals, fuel pipes, and other fluororubber seals, are now controlled by foreign conglomerates. In addition, China’s level of fluororubber products in other high-end fields such as civil aviation, petroleum, chemistry and medical treatment, construction, light emitting diodes, and solar cells is lagging.

### 4.3 Weak innovation ability; significant gap in new technology development

In the future, the international synthetic rubber field will continue to strengthen technological innovation, and the development of new technologies will primarily focus on product innovation, process innovation, and environmental friendliness.

With regard to product innovation, new synthetic rubber products with new structures and performance are primarily developed by relying on basic research results, such as controllable free radical polymerization and controllable positive ion polymerization. Research regarding synthetic rubber enterprises in China in this field has only started.

With regard to process innovation, innovation research is primarily performed to optimize the production process, improve equipment, further develop product application formula, etc., to enhance the comprehensive technical level of the plant. The originality of synthetic rubber enterprises in China is limited.

To secure environmental friendliness, the first step is to innovate and develop new grades of high-performance synthetic rubber for producing green tires to comprehensively improve the wet skid resistance, rolling resistance, and fuel economy of tires; the second step is to develop new additives and filling oils that satisfy the requirements of environmental protection laws and regulations around environmental protection requirements; the third step is to develop synthetic rubber using biomass as a raw green material. Currently, market-oriented professional technical service support is insufficient for the development of new brands such as high-performance SSBR and rare-earth isoamyl rubber for green tires.

### 4.4 Effect of Sino-US trade friction on synthetic rubber field

The Sino-US trade friction has affected the rubber industry for many years. Since 2009, the United States has successively implemented several additional tariffs for Chinese passenger cars and light truck tires exported to the United States. The special protection case of tires has significantly affected China’s tire exports, particularly the low-end tire field. China’s synthetic rubber exports to the United States are relatively small; however, a large number of them are exported in the form of rubber products. The Sino-US trade friction has significantly affected China’s rubber product exports, resulting in a decline in the demand for synthetic rubber products and a decline in the operating rate of enterprises. Meanwhile, although most of high-end or special rubber grades are not imported from the United States, the supplier countries may restrict their exports to China under the pressure of the United States, thereby affecting related fields.

China’s synthetic rubber industry is independent of all general products and technologies, thereby affording strong strategic support for ensuring national economic development. However, many special-purpose brands still depend on imports; therefore, we should focus on developing high-end synthetic rubber products and compensate for the shortcomings through the integrated development of production, education, and research.

# 5 Strategic objectives and development tasks of high-performance synthetic rubber materials in China

## 5.1 Strategic objectives

### 5.1.1 High-end materials

The development of functionalized SSBR, neodymium cis-butadiene rubber, and star halogenated butyl rubber must be emphasized. They are applied in high-performance tire treads, sidewalls, and inner liners, constituting 60% of the total consumption of synthetic rubber.

Polarized SBS, SIS, hydrogenated SEBS, SEPS thermoplastic elastomer, long-chain branched ethylene-propylene rubber, functionalized high-impact styrene-butadiene resin, etc., are primarily used in sealing and waterproofing, adhesives, wires, and cables, constituting 21% of the total consumption of synthetic rubber.

Products such as special HNBR, TPV, high-performance silicone rubber, and fluoroether rubber have been developed. They are primarily used in marine rubber products, waterstops, rubber products for rail transit, aerospace, special operations, and other fields. A relatively complete evaluation system of high-performance silicone rubber functional fillers and a product application evaluation system should be established by 2025. Furthermore, special monomers for fluoroethers should be realized, and perfluoroether rubber resembling that of the international advanced level as well as fluororubber without secondary vulcanization should be prepared.

### 5.1.2 Green process

The main purpose of green development is to improve the existing production process and realize energy saving and consumption reduction, including the development of new reactors, energy-saving technology of synthetic rubber drying process, and quality control technology of synthetic rubber production. Green production and environmental protection technologies, including low emission production, volatile organic compound treatment and sewage reduction, low energy consumption production, emulsion polymerization concentration, and environmentally friendly auxiliary substitution technologies should be developed, and technologies for synthesizing diolefins based on biomaterials should be investigated.

### 5.1.3 Intelligent production

Utilizing artificial intelligence network technology and data resource integration, high-speed and effective research regarding the molecular design, synthesis technology, and processing application of elastomer materials can be realized.

China’s industry has entered the 4.0 era, and new theories and tools such as digitalization, intelligence, modularization, and networking have been introduced into the development of synthetic rubber materials technology, forming a complete set of self-owned databases that simulate the product structure, performance, and possible application fields through computer models. Hence, the basic research, production technology development, and product application research of products involve a complete set of simulation evaluation systems. Customers can customize high-end products at any time based on their requirements. Furthermore, they can rapidly design, develop, produce, and enter the market, as well as lead the international market in technology development and product application development; in this regard, high-end products are expected to exceed 70%.

Advanced manufacturing, equipment, automatic control, and environmental protection technologies must be integrated to realize intelligent, green, and low-carbon synthetic rubber production processes. Basic research, production technology development, and product application research of products form an efficient chain and realize the intelligent and efficient customization system of customers–R&D–production–sales.

## 5.2 Key development tasks

### 5.2.1 Functionalized SSBR

High-performance energy-saving tread compounds with low oil consumption, high safety, low noise, and high comfort should be developed. Furthermore, high-end brand SSBR should be developed, functional SSBR production technology with independent intellectual property rights formed, and an intellectual property protection network for new products and methods of high-performance SSBR built in China to reach the international advanced level in technology.

### 5.2.2 HNBR

Foreign HNBR products are primarily focused on conventional HNBR brands with a nitrile content of 22%–

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45%. China is undergoing HNBR industrialization, and the target brand is the primary conventional HNBR product. Foreign companies have banned the sale of special brand products. Therefore, the development of special brand HNBR rubber will become the focus of development, including HNBR with a wide temperature range, HNBR with low-temperature and oil resistance, and the development of new special HNBR products.

#### 5.2.3 Butyl/halogenated butyl rubber

Effort should be expended toward strengthening basic research, optimizing molecular structure design, as well as developing branched butyl rubber and new halogenated butyl rubber products with specific performance. Additionally, the design and manufacturing technology of key core equipment should be further developed. Furthermore, efforts should be expended to upgrade existing domestic devices and production technologies, form stable large-scale production, strengthen the development and marketing of product processing and application technologies, and achieve all-round technological breakthroughs from basic research, industrial technology, and processing technology to demonstrate and apply high-performance products in cutting-edge fields by 2035, with the goal of reaching world-class level in terms of production technologies and products [11].

#### 5.2.4 Styrene thermoplastic elastomers and their hydrogenated products

By introducing monomers with high glass transition temperatures into styrene thermoplastic elastomers and introducing polar acrylate branch chains into the polymer main chain, a polymer with a novel structure was designed and synthesized, thereby improving the temperature resistance, wear resistance, and elasticity of the material, as well as improving the comfort, wear resistance, and temperature resistance of existing non-pneumatic tires.

The commercialization of functionalized styrene thermoplastic elastomers such as sulfonated modified SBS, epoxidized SBS, and high polarity SBS have been realized and successfully applied in special fields such as oil fields and medical treatment. Research regarding new synthetic methods, particularly the latest progress in the synthesis of non-styrenic thermoplastic elastomers based on reversible addition-fragmentation chain transfer living radical polymerization, should be performed. The establishment of a new thermoplastic elastomer technology development platform and performance evaluation system will provide a basis for the large-scale application of new functional thermoplastic elastomers.

#### 5.2.5 IR

Rare-earth catalysts are used in cis-isoprene rubber plants in China, and they perform better than traditional Ti-based catalytic IR. However, their production technology is still being developed, and the catalyst systems, preparation methods, reaction equipment, and polymerization processes can be further improved.

#### 5.2.6 TPV

To adapt to the rapid development of rubber–plastic blend thermoplastic elastomer materials, the technical development and application research of traditional TPV materials such as EPDM/PP and IIR/PP must be strengthened; meanwhile, with the continuous development and maturity of dynamic vulcanization technology and related mechanisms, high-performance special TPV materials based on different components that satisfy different performance requirements are constantly emerging. In the future, we should focus on developing isobutylene-p-methylstyrene copolymer rubber/nylon TPV with high gas barrier properties, acrylate-rubber-based TPV and fluororubber-based TPV with high-temperature resistance and chemical medium resistance, silicone rubber-based TPV with high somatosensory compatibility, and biodegradable TPV with environmental protection.

#### 5.2.7 Special silicone rubber

The key to the development of high-temperature resistant silicone rubber, such as phenyl (ether) silicone rubber and silicone rubber containing special elements (such as boron and nitrogen) is the large-scale preparation of special high-temperature resistant silicone monomers. These monomers include disilanol containing high-temperature resistant elements, such as phenylene disilanol, diphenyl ether disilanol, and carborane disilanol, as well as special living polymerization monomers, such as bisureasilane. We should further develop the preparation of high-temperature-resistant silicone monomers, preparation of special catalysts, and control of polymerization reaction the soonest possible.

#### 5.2.8 Special fluorine rubber

The automobile industry is the main consumption field of fluororubber, constituting approximately 40% of the total consumption of fluororubber, 25% of the petrochemical industry, and 35% of aerospace, aviation, and other industries. With the increasing requirements of energy saving and environmental protection in various industries, traditional rubber materials can no longer satisfy the new requirements, thereby allowing fluorine rubber to replace other rubber products. Compared with foreign fluororubbers, China's fluorourubber is primarily deficient in special polymerized monomers, and the automation and intelligence of production equipment are relatively outdated. The synthesis technology of special polymerized monomers and the automation and intelligence of lifting equipment are key to the breakthrough of fluororubber products in the future.

## 6. Measures and suggestions

### 6.1 Establish plans, focus on support, and strengthen collaborative innovation in industrial chain

Based on the general trend of the development of synthetic rubber technology worldwide, special innovation projects should be established at the national level, with key support, enterprises as the main body, and collaborative innovation of production, education, and research. We should actively conduct research on high-performance synthetic rubber materials and jointly develop them from the aspects of synthesis mechanism, process route optimization, equipment and digital automation, and development of new application fields. Hence, a complete upstream and downstream innovation chain can be formed, and the development of the industry can be accelerated to satisfy the requirements of the rapid development of new high-performance synthetic rubber materials in China.

### 6.2 Strengthen macro-control and optimize industrial structure

Efforts should be expended to strengthen the role of macro-control in macro-industrial policy, credit policy, and industry organization, formulate relevant policies, encourage enterprises to perform R&D and industrialize high-tech synthetic rubber materials, limit new or expanded projects from low-end technology sources, enhance the ability of R&D and control of core technologies, and optimize the industrial structure.

### 6.3 Establish national-level innovation platform and create first-class innovation team

Efforts should be expended to strengthen the training of scientific research personnel, focus on scientific research strength, optimize the reward mechanism for the transformation of scientific research achievements, enhance internal motivation, establish a high-performance rubber material innovation team with first-class development, innovation ability, and self-development ability in the world, and promote the development of the rubber industry.

## References

[1] Jiao S K, Zhou Y H. Rubber elastic physics and synthetic chemistry [M]. Beijing: China Petrochemical Press Co., Ltd., 2008. Chinese.

[2] The Research Group of Chemical, Metallurgical, and Material Fields. Preliminary study on impact of disruptive technologies in chemical, metallurgical, and material fields [J]. Strategic Study of CAE, 2018, 20(6): 34–41. Chinese.

[3] Cao X H, Yuan Q T, Liu P C. Development strategy for China's petrochemical engineering science and technology to 2035 [J]. Strategic Study of CAE, 2017, 19(1): 57–63. Chinese.

[4] Qian B Z. Startup of Chinese first SEPS plant [J]. Rubber Science and Technology, 2017, 15(10): 33. Chinese.

[5] Yang X X, Wang D M, Lyu X D. The analysis and prospect of domestic and foreign synthetic rubber market [J]. Petroleum & Petrochemical Today, 2019, 27 (6): 13–20. Chinese.

[6] IISRP. Worldwide rubber statistical [R]. Houston: International Institute of Synthetic Rubber Producers, Inc, 2017–2019.

[7] China Synthetic Rubber Industry Association Secretariat. Retrospection and prospect of domestic synthetic rubber industry in 2017 [J]. China Synthetic Rubber Industry, 2018, 41(2): 81–83. Chinese.

[8] Wu Y F, Huang W, Xu J S. Current situation and development trends of production & consumption on fluoroelastomers at home and abroad [J]. New Chemical Materials, 2013 (3): 1–5. Chinese.

[9] Jin H. Construction of industrial chain based on chlorine recycling of trichlorosilane [J]. Guangdong Chemical Industry, 2020, 47(12): 120–121. Chinese.

[10] Zhao L Q. Analysis on the development trend of China sillicone industry chain [J]. Chemical Industry, 2019, 37(1): 10–20. Chinese.

[11] Cao X H. Innovation drives structural adjustment to strengthen China's synthetic rubber industry (II) [J]. China Rubber, 2014, 30(21): 18–21. Chinese.