

Development Status and Trend of Lithium Ion Cathode Materials

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Abstract: Driven by carbon peaking and carbon neutrality goals and market demand, China's new energy vehicles have entered a stage of rapid development, which has led to significant changes in the industry of power battery cathode materials and its market pattern. This paper introduces the classification, advantages and disadvantages, and application scenarios of lithium ion cathode materials and focuses on the market status and industrial pattern of lithium iron phosphate cathode materials and ternary cathode materials before discussing the future industrial development trend.

Keywords: Cathode Material, Market Status, Industrial Pattern, Development Trend.

1. Classification and Application Scenarios of Lithium Ion Cathode Materials

The market demand for lithium ion cathode materials has rapidly expanded in recent years. At present, the mainstream lithium battery cathode materials in the market include ternary materials (NCM, NCA), lithium iron phosphate, lithium cobaltate, and lithium manganate. The four materials are used in different scenarios due to their differences in

specificity. Ternary cathode materials are mainly used in the field of new energy passenger vehicles in China; A small portion of ternary cathode materials is used in the field of energy storage overseas, and others are used in the field of new energy passenger vehicles. Lithium iron phosphate cathode materials are mainly used in the field of NEVs and energy storage; Lithium cobaltate cathode materials are mainly used in 3C consumer electronics field; Lithium manganate cathode materials are mainly used in electric bicycles and electric tools. Their specific performance, advantages and disadvantages are shown in Table 1 [1-6].

Table 1. Classification of cathode materials for lithium batteries

	Ternary material		Lithium iron phosphate (LFP)	Lithium manganate (LMO)	Lithium cobaltate (LCO)
	Nickel cobalt manganese (NCM)	Nickel cobalt aluminum (NCA)			
Material structure	Layered oxide	Layered oxide	Olivine	Spinel	Layered oxide
Theoretical specific capacity (mAh/g)	273-285	273-285	170	148	274
Voltage range (V)	2.8-4.5	2.5-4.6	3.2-3.7	3.0-4.3	3.0-4.5
Cycle life	800-2000	800-2000	4000-6000	500-2000	500-1000
Thermal stability	Generally, it becomes worse with the increase of Ni content	Poor	Excellent	Good	Poor
Advantage	High energy density	High energy density, good low-temperature performance	Low cost, good safety and long cycle life	Low cost, good safety performance	High compaction density, high energy density and high working voltage
Shortcoming	Easy to swell in high temperature, poor cycling and safety	Poor cycling and safety performance	Low energy density and poor performance in low temperature	Low energy density and poor cycling performance in high temperature	High raw material cost and high cobalt price
Main application fields	New energy passenger vehicles	New energy passenger vehicles	New energy passenger vehicles, commercial buses, energy storage	Electric tools, electric bicycles	3C Consumer Electronics

From the perspective of the shipment trend of lithium cobaltate and lithium manganate cathode materials: Thanks to the rapid growth of 3C (computer, communication and consumer electronic) consumer electronics, China's shipments of lithium cobaltate have increased significantly. With the gradual saturation of 3C consumer market, the growth rate of lithium cobaltate shipments slowed down

significantly. Lithium manganate cathode materials are mainly used in the field of electric bicycles and electric tools with the former taking up a bigger share. In 2021, the amount of lithium batteries for electric bicycles will be 10.5GWh. It is estimated that 8.2GWh lithium batteries will be used for making electric bicycles in 2022, a year-on-year decrease of 21.9%, mainly because the current cost factors have delayed

the process of lithium electrification.

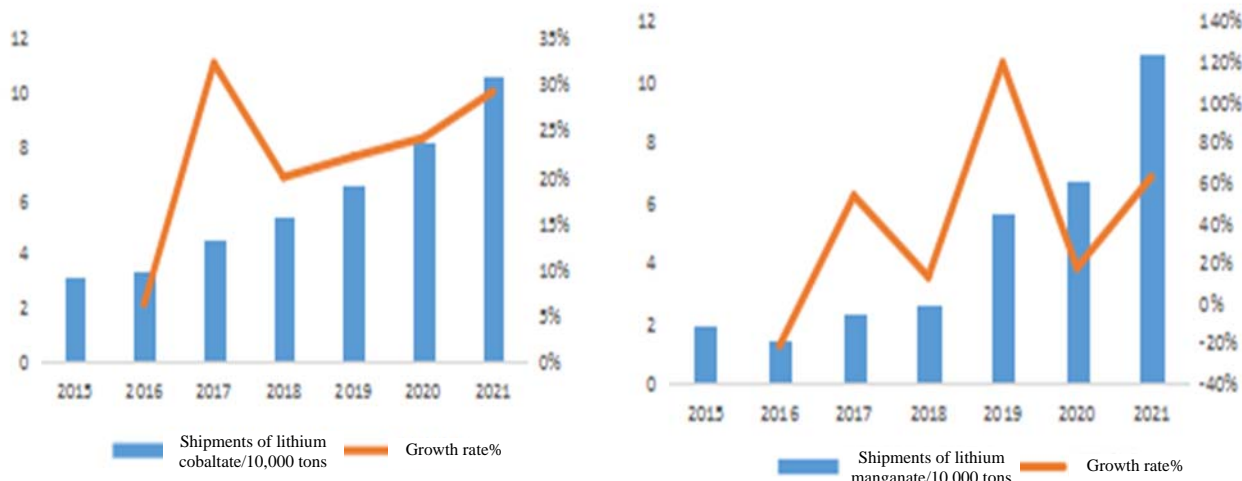


Figure 1. Shipments of lithium cobaltate and lithium manganate cathode materials in China

2. Shipment and Market Pattern of Ternary Cathode Materials and Lithium Iron Phosphate Cathode Materials

After more than ten years of development, China has become one of the major manufacturers and consumers of lithium battery cathode materials in the world. Since 2009, China has officially launched the promotion and application demonstration project “One Thousand Vehicles in Ten Cities”. NEVs are mainly used in urban public transport, government and other fields; purchase for private purposes only takes up a very small share; Moreover, due to the immature battery technology research and development system at that time, NEVs mainly used lithium iron phosphate batteries, which led to higher consumption of lithium iron phosphate cathode materials. In 2014, the State Council issued the second Guiding Opinions on Accelerating the Promotion and

Application of New Energy Vehicles which put in place tax incentives for NEVs. Driven by policy subsidies and the demand for higher mileage, the installed capacity of ternary batteries increased significantly, driving the rapid growth of the shipment of ternary cathode materials which exceeded the shipment of lithium iron phosphate cathode materials in 2017. During 2015-2020, the shipment of ternary cathode materials maintained relatively rapid growth with a compound annual growth rate of 45%; The shipment growth rate of lithium iron phosphate cathode materials is relatively slow with a compound annual growth rate of 32%. Since 2021, with the improvement of lithium iron phosphate battery technology and its own advantages in safety performance, its penetration rate in the field of power batteries has increased, and rapid development of energy storage, the demand for lithium iron phosphate cathode materials has risen sharply again with the shipment volume of 480,000 tons, a year-on-year increase of 287%; Moreover, its shipment volume exceeds that of ternary cathode materials.

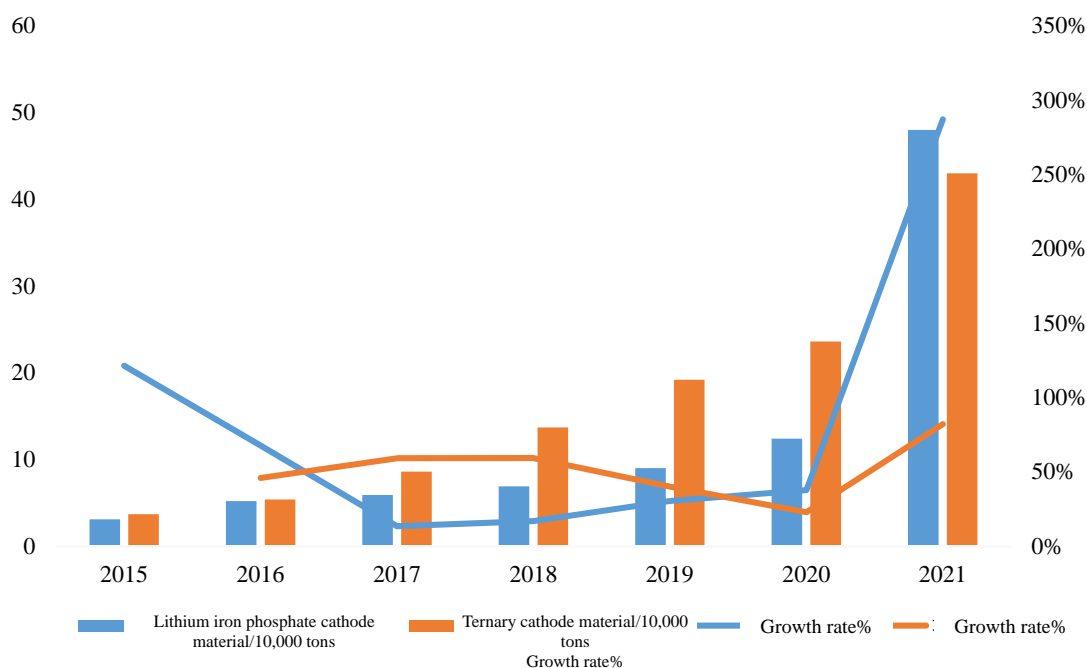


Figure 2. Shipments of ternary cathode materials and lithium iron phosphate in China

From the perspective of market share of ternary cathode materials, the top five enterprises in 2021 are Ningbo Ronbay Lithium Battery Material Co., Ltd., Tianjin B&M Science and Technology Co., Ltd, Beijing Easpring Material Technology Co., Ltd, Hunan Changyuan Lico Co., Ltd and Guizhou ZEC, accounting for 14%, 12%, 10%, 9% and 8% respectively; their CR5 is about 50%. Among them, the market share of Ronbay Technology has always ranked first during 2017-

2021, and the shipment volume has shown a notable upward trend. The shipment of Easpring Material Technology grew the fastest from 2017-2021 with a compound annual growth rate of 53%, followed by B&M Science and Technology and Ronbay Technology. In terms of the absolute increment from 2017-2021, Ronbay Technology, Easpring Material Technology and B&M Science and Technology ranked first.

Market pattern of ternary cathode materials in China in 2021

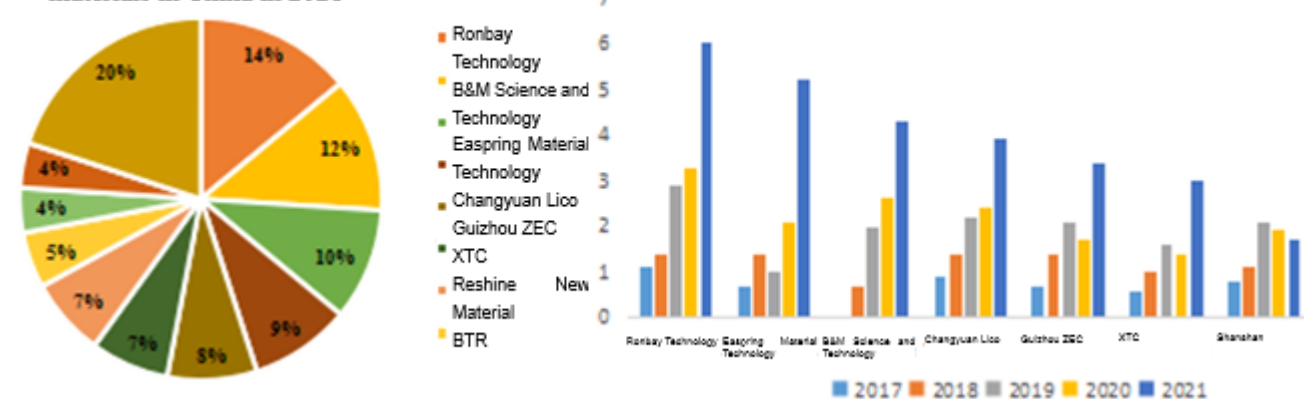


Figure 3. Market pattern and shipment of ternary cathode materials in China

With regard to the market share of lithium iron phosphate cathode materials, the top five enterprises in 2021 are Hunan Yuneng, Dynanonic, Lopal, Hubei Wanrun and Zontonec Technology, accounting for 25%, 20%, 9%, 9% and 8% respectively; their CR5 is about 70% with relatively high industrial concentration. However, from the perspective of enterprise distribution of CR5, the leading enterprises are Dynanonic and Hunan Yuneng; After Lopal acquired all the

assets of LFP cathode materials under BTR through its holding subsidiary Changzhou LBM, its market share in 2021 ranked third. From the perspective of absolute increment from 2018 to 2021, Hunan Yuneng ranks first, followed by Dynanonic; In terms of the compound annual growth rate of 2018-2021, Hunan Yuneng has the highest compound annual growth rate of 210%; Lopal ranked the second with a compound annual growth rate of about 92%.

Market pattern of lithium iron phosphate cathode materials in China in 2021

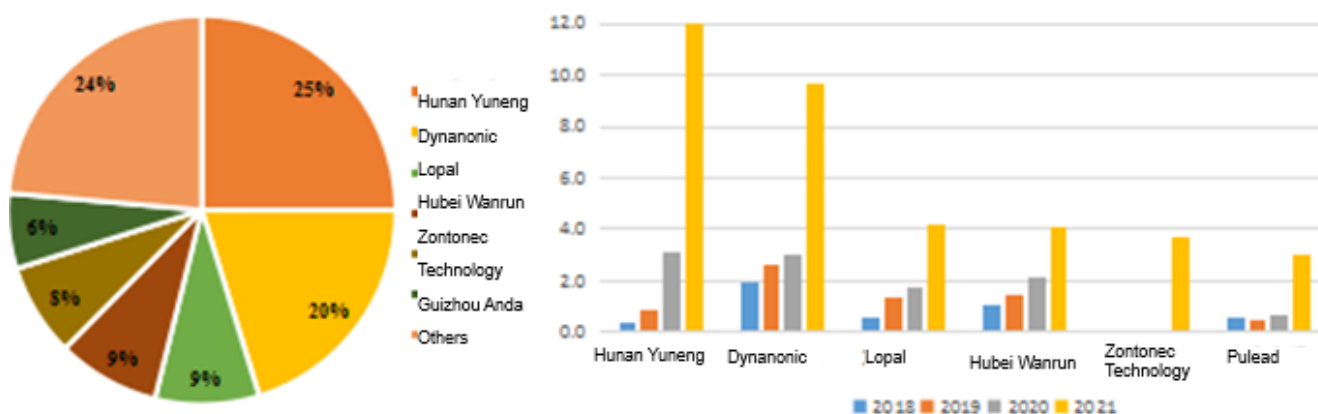


Figure 4. Market pattern and shipment of lithium iron phosphate cathode materials in China

3. In the Future, The Rapid Growth of Ternary Cathode Materials and Lithium Iron Phosphate Cathode Materials Will Continue

As the global electric vehicle market shifts from being policy-driven to being consumption-driven, and countries become more determined to combat climate change, the NEV

industry has entered a stage of rapid development. In 2021, 3.545 million NEVs will be manufactured and 3.521 million sold, with a year-on-year increase of 159.5% and 157.6% respectively. In the first half of 2022, the production and sales volume of NEVs will be 2.653 million and 2.591 million respectively. It is expected that NEVs will continue to develop rapidly. In terms of installed capacity, in the first half of 2022, the installed capacity of ternary battery and lithium iron

phosphate battery will be 30.1 GWh and 22.2 GWh respectively, with year-on-year growth of 139% and 372%; The proportion of its lithium iron phosphate battery increased from 38.2% in 2021 to 42.3%. The technical trends of ternary cathode materials are mainly high voltage, high nickel, high magnification and single crystal. Lithium iron phosphate battery will continue to further penetrate the field of NEVs due to its advantage in technology, cost, safety and other factors.

Thanks to the rapid growth of terminal demand with rich

application scenarios, the global shipment of energy storage batteries in 2021 will be about 66.3 GWh, a year-on-year increase of 133%. According to industry forecasts, the global shipment of lithium energy storage batteries is expected to be 416 GWh by 2025 with a compound annual growth rate of 58.3%. Lithium iron phosphate has advantages in cycle times, service life and material recovery, and lithium iron phosphate cathode materials are mainly used in the domestic energy storage field.

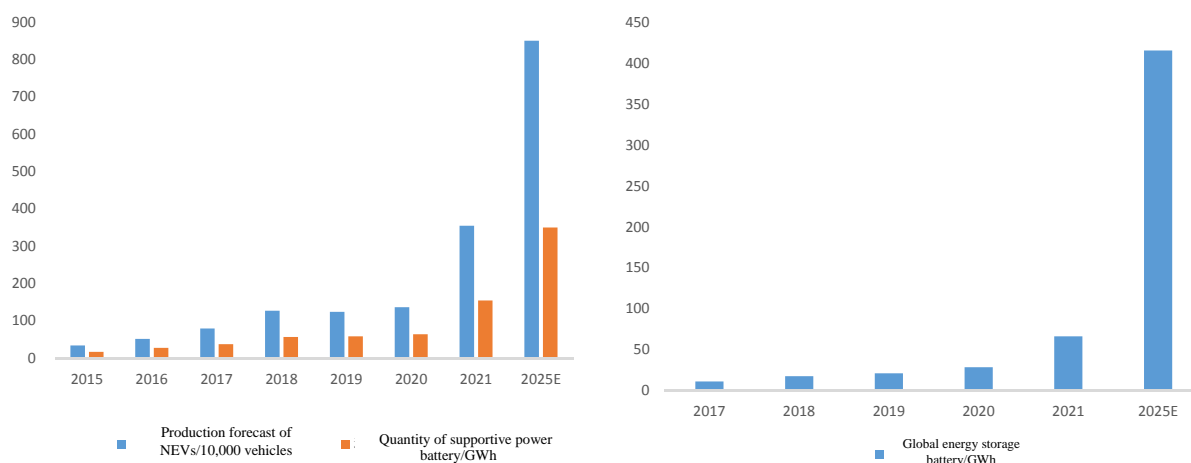


Figure 5. Development status and trend of NEVs and energy storage batteries

Table 2. Capacity expansion plan of major domestic ternary cathode material enterprises in 2021

Corporate name	Project	Production capacity+product
Ronbay Technology	Phase-V Project of Hubei Ronbay	70,000 tons of high-nickel cathode materials
	Phase-II and subsequent projects of Guizhou Ronbay	85,000 tons of high nickel cathode materials
	Production and construction project of high nickel cathode with an annual output of 20000 tons in South Korea	20,000 tons of high nickel cathode materials
	Rongbai Xiantao Strategic Cooperation Framework Agreement	400,000 tons lithium cathode material
Beijing Easpring Material Technology	Dangsheng Technology (Changzhou) Lithium Battery New Material Industrial Base Phase II Project	50,000 tons of high nickel cathode materials
Changyuan Lico	Phase I expansion project of cathode materials for automotive lithium batteries	40,000 ton lithium battery cathode material for vehicles
	Industrialization project of 40,000-ton lithium ion battery materials at Haijing Base(Phases I and II)	20,000 tons of ternary materials
XTC	The third phase of the industrialization project of lithium ion battery materials with a potential annual output of 40,000 tons in Haijing Base	20,000 tons of ternary materials
Guizhou ZEC	Construction project of lithium ion battery cathode material production line (Shawen Phase-II)	12,000 tons of cathode materials
	Construction project of lithium ion power battery ternary material production line (Yilong Phase-II)	20,000 tons of ternary materials
Shanshan	Production of 100,000 tons of cathode materials of Changsha base	100,000 tons of cathode materials
	29,000-ton cathode material project of Thunip Corp., Ltd	29,000 tons of cathode materials
Huayou Cobalt	50,000-ton anode material project of Chengdu B&M	50,000 tons of cathode materials
	50,000-ton high-nickel cathode material project of Guangxi B&M	50,000 tons of high-nickel cathode materials
BTR	50,000-ton high nickel cathode materials of Jiangsu BTR	50,000 tons of high-nickel cathode materials
Kelong New Energy	Project of ternary positive electrode materials with an annual output of 4,000-ton high-performance power battery	4,000-ton ternary cathode materials

4. The Trend of Production Expansion of Cathode Material Enterprises

The rapid growth of downstream consumer demand for ternary cathode materials and lithium iron phosphate cathode materials has boosted the expansion of cathode material enterprises.

At present, ternary cathode material enterprises have started a new round of production expansion, mainly in the field of high nickel. The planned capacity of ternary cathode material exceeds 1 million tons. The capacity expansion plan of major enterprises is shown in Table 2. It can be found from the current production and development direction of enterprises that some producers of lithium cobalt oxide cathode materials are also accelerating their production of ternary cathode materials due to the saturation of the

consumer electronics field and the rapid development of the power battery field. For example, XTC is the largest supplier of lithium cobaltate in China, accounting for about 50% of the domestic supply; Relying on its lithium cobaltate technology reserve in the field of high-performance ternary materials, the company is also actively making inroads into the power battery cathode material market.

At the same time, ternary cathode material enterprises are also gradually expanding to the lithium iron phosphate material market to make themselves into a lithium battery cathode material platform enterprise. Different from other enterprises entering the field of lithium iron phosphate cathode materials, ternary cathode material producers enjoy the advantage of customer channels. At present, the world's major power battery enterprises are either developing lithium iron phosphate batteries or have produced them in mass.

Table 3. R&D and production progress of lithium iron phosphate batteries in major global power battery enterprises

Battery enterprises	Installed capacity in 2021 (GWh)	Market share in 2021	Progress of lithium iron phosphate battery projects
CATL	93.68	32.1%	Mass production
LGES	60.25	20.6%	R&D will start at the end of 2020, and a pilot production line is expected to be built in 2022
Panasonic	46.64	16%	No R&D plan
BYD	23.95	8.2%	Mass production
Samsung SDI	9.66	3.3%	No R&D plan
SK On	14.36	4.9%	Under development
AVIC Lithium	8.60	2.9%	Mass production
Envision AESC	4.13	1.4%	Mass production
Gotion High-tech	7.13	2.4%	Mass production
EVE	2.26	0.8%	Mass production

In the second half of 2021, the leading enterprises of ternary cathode materials will announce the production expansion plan of lithium iron phosphate. Among them, Changyuan Lico will mainly build its own production line, Ronbay Technology and Easpring Material Technology will cooperate with upstream precursor enterprises, and XTC, Huayou Cobalt, GEM, etc. will jointly invest in the lithium iron phosphate integrated project through joint ventures with chemical enterprises and lithium resource enterprises. As of March 2022, The producers of ternary cathode materials have announced plans to expand the production of lithium iron phosphate by more than 1 million tons.

In addition to the horizontal expansion of cathode material enterprises (such as accelerating the expansion of ternary cathode material enterprises with producers mainly producing lithium cobalt oxide cathode materials, and the related producers of ternary cathode materials have started to diversify into the productions of lithium iron phosphate cathode materials), some new players have also entered the field of cathode materials. New players are mainly enterprises that have made cathode materials their main business through acquisition. For example, Mianyang Fulin Precision Co., Ltd acquired Hunan Shenghua Science & Technology Co. Ltd. in

2016 and entered the lithium iron phosphate cathode industry; In June 2021, Lopal Technology acquired BTR's lithium iron cathode business and entered the lithium iron phosphate cathode industry. Some enterprises have upstream raw materials or related enterprises in the industrial chain, and enter the field of cathode materials with advantages in cost or raw material. For example, Jinchuan Group Co., Ltd. indirectly controls Nantong Reshine by increasing its capital in Hunan Reshine New Materials Co., Ltd. for the second time to 67%; Jinchuan has nickel resources and cobalt resources in the upstream. Through resource advantages, it has entered the field of ternary cathode materials, giving it significant advantages of raw material cost in the production process. The main product of CNNC Hua Yuan Titanium Dioxide Co., Ltd is rutile titanium dioxide, which is comprehensively distributed in the upstream and downstream of the industrial chain to build a green recycling base of "sulfur – phosphorus – iron – titanium – lithium". It mainly implements recycling production based on by-products (waste sulfuric acid, ferrous sulfate) in the production process of titanium dioxide, develops a lithium iron phosphate project with an annual output of 500,000 tons, and enters the field of lithium iron phosphate cathode materials with relatively low

production cost.

Table 4. Enterprises in the ternary cathode industry chain are entering the lithium iron phosphate material market

Company	Development	Announcement time
Changyuan Lico	The wholly-owned subsidiary invested in a project with an annual output of 60,000 tons of lithium iron phosphate, which is planned to start construction in January 2022 and be put into production in April 2023	December 2021
Beijing Easpring Material Technology	Cooperate with CNGR to invest in the development of phosphorus resource, phosphorus chemical industry, lithium iron phosphate, resource recycling and supporting integrated industrial projects with a total capacity of no less than 300,000 t/a	November 2021
CNGR	Plans to build an integrated project of production line with an annual output of 200,000 tons of iron phosphate and lithium iron phosphate materials in Kaiyang, Guizhou Province, and to build a supporting phosphate rock to produce phosphoric acid or yellow phosphorus, monoammonium phosphate within the scope of the chemical industry park, as well as supporting mining areas and phosphate rock mining	December 2021
XTC	Plans to work with Yahua Lithium and Xiamen Cangya to build Ya'an Base with 100,000-ton annual output of lithium iron phosphate, with a total investment of no less than 10 billion yuan. The first phase of the project will have an annual output of 20,000 tons, with an estimated investment of no less than 1.2 billion yuan. The construction period is two years, and it is expected to be put into production in 2023	September 2021
Huayou Cobalt	Jointly invested 300 million yuan with Xingfa Group to build a 300,000 t/a iron phosphate project. The project will be constructed by stages. The first phase of the project is a 100,000 t/a iron phosphate project (500,000 t iron phosphate, 500,000 t lithium iron phosphate)	November 2021
GEM	Jointly invested and built a 150,000 t/a iron phosphate project and a 100,000 t/a lithium iron phosphate project with Yonfer, with an investment of 1 billion yuan (iron phosphate); takes 50,000-ton as the production unit and will put the first phase into operation before August 2022	January 2022

5. Summary

(1) At present, the mainstream cathode materials include lithium cobaltate, lithium iron phosphate, lithium manganate and ternary materials, among which lithium cobaltate is mainly used in the 3C field; lithium manganate is mainly used in the field of low-speed electric vehicles; lithium iron phosphate is mainly used in the field of electric vehicles and energy storage, and ternary materials are mainly used in the field of electric vehicles.

(2) The field of electric vehicles and energy storage is the core growth point of the new energy industry, and ternary cathode materials and lithium iron phosphate cathode materials as the mainstream materials have attracted more enterprises into these fields, and the competition in the industry is becoming increasingly fierce.

(3) The trend of industrial integration is becoming increasingly obvious. In order to improve their competitiveness, enterprises begin to expand into the upstream end of raw materials; Enterprises at the raw material end are also extending the industrial chain downward. In addition, enterprises are also conducting horizontal expansion

to increase their product types. It can be seen that the industry is developing both vertically and horizontally.

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