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# Back-End Electronics Manufacturing Equipment in China and Its Key Components

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**Abstract:** Electronics manufacturing is a strategically important pillar in China's economy. As the supply and ecological chains of the global electronics manufacturing industry are currently being reshaped, research on back-end electronics manufacturing equipment and their key components has become extremely important for the high-quality development of the electronics manufacturing industry in China. This study analyzes the development status and trends of the back-end electronics manufacturing equipment industry in China and other countries and summarizes the characteristics of international technological competition in the industry, that is, the pursuit of high-density and miniaturized electronic devices, as well as high efficiency and low cost in the manufacturing process. The electronics manufacturing equipment industry in China encounters problems such as weaknesses in independent and fundamental technologies, a single-market competition model, and severe dependence on imports. Additionally, 12 major technical fields and fundamental contents that China must focus on are summarized from the aspects of key processes, core equipment, and components. An empirical analysis is conducted on four typical electronics manufacturing enterprises to summarize their development strategies and experiences. The significance of innovation, key technologies, and market iterations in the development of related enterprises are clarified. Furthermore, corresponding countermeasures for the development of China's back-end electronics manufacturing equipment and its components are proposed from the perspectives of top-level design, industrial layout, market competition, enterprise development, technological innovation, and talent training.

**Keywords:** back-end electronics manufacturing; supply chain transformation; electronics manufacturing equipment; multichip device integration; enterprise case analysis

## 1 Introduction

Electronics manufacturing is one of the most strategically important and innovative industries in China; in 2020, it accounted for 12.1 trillion CNY of revenue (approximately 11.4% of China's total engineering revenue) [1,2]. Over the past few years, lockdown orders and the increased popularity of telecommuting owing to the COVID-19 pandemic have resulted in a significant increase in the demand for personal computers, tablets, smartphones, and other electronics, and consequently, the further expansion of the electronics manufacturing industry. The high-quality electronics industry is crucial for the stability and robust development of China's economy.

The global electronics manufacturing industry has undergone several transformations. In the 1960s, because of the evolution of industrial structures, the United States outsourced many labor-intensive industries, including back-end electronics manufacturing, overseas. In the 1970s, Japan outsourced the same industries to the "four Asian

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tigers": Hong Kong of China, Singapore, South Korea, and Taiwan of China. In the 1990s, other developed countries began outsourcing their electronics manufacturing industries to mainland China. Since the beginning of the 21st century, as the cost of Chinese labor has increased, companies have begun to outsource the manufacturing of end products to India, Vietnam, and other countries with lower labor costs. Despite these manufacturing trends, developed countries retain control over technology, particularly research and development. Therefore, China's electronics industry faces a dilemma: high-end equipment is manufactured in developed countries, whereas mid-level and low-end manufacturing is outsourced elsewhere.

In recent years, because of the accelerated application of new technologies such as fifth-generation mobile communication (5G) technology, artificial intelligence (AI), and ultra-high-definition displays, markets related to these technologies have flourished. The concept of reverse globalization has emerged; proponents of this concept believe that relocating each part of the supply chain [3–5] to ecologically reconstruct it is warranted. This is a historical opportunity for the development of the electronics manufacturing industry.

Electronics manufacturing is generally divided into front-end and back-end industries. Chip manufacturing, which includes chip design, wafer production, and high-precision lithography, occurs primarily in the front-end industry, whereas chip packaging, device processing, and end-product manufacturing occur in the back-end industry. Regarding the front-end industry, China has conducted research and implemented relevant strategies for the development and manufacturing of high-end chips. However, China's back-end electronics manufacturing industry has been lagging the corresponding international industries for more than 20 years, and insufficient research has been conducted on the outcomes of and development strategies for the back-end industry. Therefore, this paper analyzes the development of relevant equipment and key components of China's back-end electronics manufacturing industry, clarifies relevant changes in the market, examines regional and enterprise-level modes of development in the back-end industry, and summarizes the trends and problems in the back-end electronics manufacturing industry and related industries in China. Thereafter, this paper proposes directions for future technological development in the industry and presents an empirical analysis of representative enterprises, the results of which may serve as a reference for the development of back-end electronics manufacturing enterprises and scientific decision-making by public management departments.

## 2 Development status of the global back-end electronics manufacturing equipment industry

### 2.1 Changes in the global market

From a technical perspective, the development of the electronics manufacturing industry relies on two main product types: high-end chips and high-end manufacturing equipment, both of which are technology- and capital-intensive and are characterized by high fixed costs and rapid iteration [6,7]. Core technologies used in front-end electronics manufacturing, such as chip design tools and high-performance lithography machines, are generally monopolized by Western countries. Most of the high-end equipment required for back-end manufacturing is monopolized by developed countries, such as the United States, European countries, and Japan.

Back-end electronics manufacturing equipment can be classified according to the characteristics of both the industry and equipment itself. Most back-end electronics manufacturing equipment comprises the equipment and technologies used for processing semiconductors; packaging chips; producing electric vacuum devices and flat-panel displays, electronic components and modules, integrated circuit (IC) substrates, printed circuit boards, and end products (through assembly lines); and testing and measuring components. Images of typical back-end electronics manufacturing equipment are shown in Fig. 1. The miniaturization and high-density interconnection of chips have accelerated the development of many front-end manufacturing technologies, including submicron lithography and precision semiconductor manufacturing. Therefore, in the field of microsystems, the boundary between front- and back-end manufacturing in the electronics industry is narrowing and the two industries are becoming integrated.

In recent years, the global electronics manufacturing equipment industry has continued to expand. In 2020, the global electronics manufacturing equipment industry had a revenue of up to 74.35 billion USD, representing an increase of 8.08% from that in 2019 [2]. The market sizes of this industry in the United States in 2016, 2017, 2018, 2019, and 2020 were 10.08 billion USD, 10.71 billion USD, 10.92 billion USD, 11.99 billion USD, and 12.67 billion USD, respectively, corresponding to an average annual growth rate of 5.88%. The United States plays a crucial role in the global electronics manufacturing industry. India's electronics industry has also maintained continuous expansion; the market sizes of the industry in 2016, 2017, 2018, 2019, and 2020 were 4.42 billion USD,

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4.92 billion USD, 5.45 billion USD, 6.02 billion USD, and 6.2 billion USD, respectively, corresponding to an average annual growth rate of 8.83%.

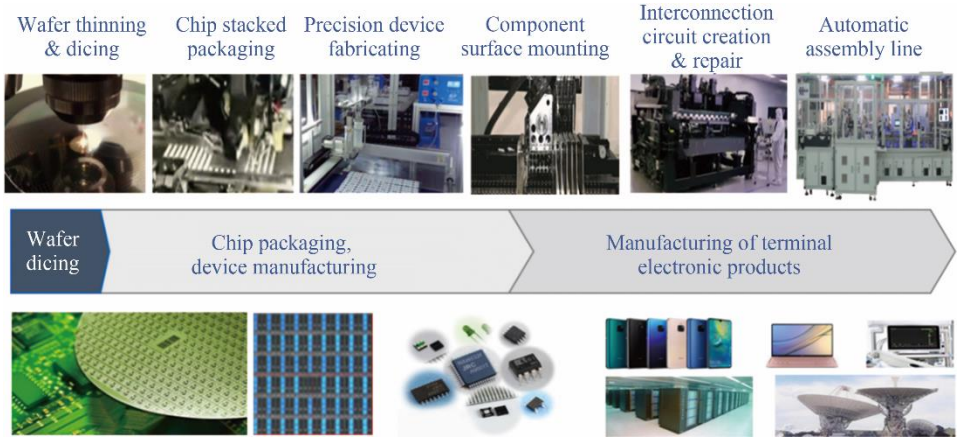


**Fig. 1.** Typical back-end electronics manufacturing equipment.

In the back-end electronics manufacturing industry, which has undergone multiple cycles of industrial transfer and scientific and technological evolution on a global scale over the past 20 years, significant advancements have been made in the manufacturing of smartphones, high-definition displays, and smart wearable electronic products. Regarding the global market of electronic products (back-end manufacturing), in 2019, China and the United States held the first and second largest shares (37.2% and 12.6%, respectively), whereas South Korea surpassed Japan to rank third in the world, with a share of 8.8% [8].

The United States has a significant technological advantage in front-end and back-end electronics manufacturing. In addition, the US government has strengthened its policies and investments to encourage industries to return to the United States and protect local industries. In 2020, to adjust for major advances in chip technology and promote the development of AI, quantum computing, wireless communication, and other emerging technologies, the Semiconductor Industry Association of America and the Semiconductor Research Corporation established a 10-year plan for semiconductors, calling on the US government to increase funding for research and development across the entire industrial chain. The *US Chip Act*, passed in 2021, encourages enterprises and government departments to invest in semiconductors and provides preferential tax policies for businesses that purchase semiconductor manufacturing equipment. In addition, to maintain its leading position in the global electronics manufacturing industrial chain, the United States has established the National Semiconductor Technology Center and an advanced packaging manufacturing and engineering base, and the US Departments of Defense and Energy has increased their investment in semiconductors. Although China's electronic end products have been ranked first in the world for many years, Western countries continue to retain exclusive access to the high-end chips and equipment required for the sustainable development of China's electronics manufacturing industry.

### 2.2 Modes of development of the global electronics manufacturing equipment industry

2.2.1 United States' mode: basic research and chain cluster development

The United States advocates the comprehensive development of electronics information technologies, attaches significance to basic and applied research, comprehensively promotes technological innovation and development by enterprises, and emphasizes the commercialization, industrialization, and cluster development of related technologies. Applied Materials, one of the largest semiconductor equipment suppliers worldwide, was established in 1967. In its early stages, Applied Materials focused on the research and development of technologies and equipment related to thin-film deposition, thereby achieving a technical competitive advantage. In its growth stage (during the 1980s), it actively responded to market demands and focused on the research and development of more segmented equipment. For example, to address the problems that severely restricted the development of the semiconductor industry at the time, such as the slowness, inaccuracy, and inconsistency of etching technologies, and to prevent the output and yield from meeting industry requirements, Applied Materials established a special research and development team that developed the plasma equipment that became popular in the industry. By 1992,

it became the largest semiconductor equipment manufacturer in the world. Over the years, because of its investments in research and development, Applied Materials has maintained a leading position in the industry, with more than 14 300 patented technologies. In addition, through the external mergers and acquisitions of high-quality enterprises, the company has continuously expanded its product line, thereby enhancing its competitiveness.

2.2.2 Japan's mode: secondary innovation based on imported technologies

Through strong government intervention, Japan has imported relevant technology and equipment, undertaken high-cost and high-risk basic research, and directly entered the stage of applied technological development and industrialization. Subsequently, with continuous government support for basic and applied research, Japan has strengthened the foundation of its industrial development and established a stable mode of industrial cluster development conducive to research- and development-driven innovation. ADVANTEST, established in 1954, is a leading supplier of semiconductor testing equipment. In its early stages, it manufactured only electronic measuring instruments; in the early 1970s, in response to Japan's demand to develop its own semiconductor industry, it cooperated with the Japan Electronics Industry Development Association and Iwatsu Electric to develop IC testing equipment. During the same period, it implemented forward-looking adjustments to products and market layouts, invested in technological research and development, and accumulated technological reserves. Subsequently, it seized the opportunity provided by the global transfer of labor in the semiconductor industry, actively expanding its overseas markets, and laying a foundation for market advantage. The company has conducted long-term, high-level investment in research and development and forward-looking accumulation of reserves, and has established 12 research and development centers in Japan, the United States, Europe, and China, providing an impetus for technological advancement.

2.2.3 South Korea's mode: strong government support

South Korea's electronics manufacturing industry is developing rapidly, and the government has played a major role in this development. South Korea has excelled in maintaining a balance between government intervention and the free market; it strategically selects key technology fields according to market demand, resulting in a mode of development that is based on a synergetic relationship between the government and private enterprises. The South Korean government leads and strategically manages industrial development, and South Korean enterprises implement relevant policies and serve as the main forces driving the development of industrial clusters.

2.2.4 India's mode: focus driving proliferation

India regards the software industry as the cornerstone of the development of the electronics manufacturing industry and has directed the allocation of scientific and technological resources to software enterprises, implemented policy measures and preferential systems, and attached importance to talent cultivation to achieve the high-level cluster development of the software industry. In addition, India has the advantage of low labor costs, and agglomeration in the back-end electronics manufacturing industry is accelerating, resulting in an industrial cluster development mode that uses software to drive the development of end products.

## 3 Development status of and problems in China's back-end electronics manufacturing equipment industry

### 3.1 Development status

China's electronics industry is extensive. Its system engineering and scientific and technological research capabilities satisfy the national demands for strategic weapons, aerospace technology, aircraft, ships, artillery control systems, and various electronic command systems, many of which are technologically advanced, even on a global scale.

First, China's electronics manufacturing equipment industry has maintained continuous growth in its output. The outputs of China's electronic product manufacturing equipment in 2016, 2017, 2018, 2019, and 2020 were 693 900, 780 200, 898 500, 987 400, and 1 032 900 sets, respectively, corresponding to an average annual growth rate of 10.46% [2]. The electronics manufacturing industry in China is primarily located in the eastern region. Jiangsu, Guangdong, and Zhejiang are the three main regions that produce electronics manufacturing equipment, outputting 279 600, 201 900, and 142 500 sets, respectively, and market shares of 27.07%, 19.55%, and 13.8%, respectively [2]. From the supply perspective, the sales of electronics manufacturing equipment were equivalent to 46.35 billion CNY in 2016 and increased to 71.68 billion CNY by 2020, representing an annual increase of 8.03%. From the perspective of demand, which is affected by the growth of the electronics market, the demand for

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electronics manufacturing equipment reached 138.11 billion CNY in 2020, reflecting an annual increase of 13.02%. Semiconductor equipment has been a major driving force in the growth of the market for electronics manufacturing equipment [2].

Second, China's electronics manufacturing industry has undergone considerable technological progress. Because of the significant market demand and acceleration of innovation, China's position in the global electronics manufacturing industry is rising; China has gradually transitioned from the low end of the industrial chain to the middle and high ends, reflecting its transition from a labor-intensive to a capital- and technology-intensive role in the industry. Over the past 20 years, strongly supported by national policies, China's electronics manufacturing industry has gradually progressed relative to competition. Compared with the remainder of the world, it has achieved the best performance in many electronic end products, such as smartphones, high-definition displays, communication products, and 5G networks. It has created many world-class technologies and products and produced a number of world-renowned enterprises, such as Huawei Technologies, ZTE, BOE Technology, TCL Huaxing Optoelectronics Technology, Xiaomi Technology, OPPO Guangdong Mobile Telecommunications, Vivo Communication Technology, and Shenzhen DJI Technology.

Third, the development of the electronics manufacturing equipment industry has accelerated. The manufacturing of equipment and key components is crucial for supporting the rapid and stable development of the back-end electronics manufacturing industry. The rapid development of China's electronics manufacturing industry is inseparable from technological advancements in electronics manufacturing equipment. Restricted by the increasing pressure of generation-difference control and the costs of procuring imported electronics manufacturing equipment, the industry's dependence on external resources, particularly in the subfields of chip device sealing and electronic end-product manufacturing, has decreased considerably over the past 10 years with the support of national policies. Progress in equipment self-dependence and domestic substitution has accelerated considerably. For example, Han's Laser Technology Industry, China Electronics Technology Group Corporation (CETC), North Huachuang Technology, Shanghai Micro Semiconductor Equipment, and numerous "specialized, special, and new" small- and medium-sized equipment enterprises have emerged, advancing the international status of China's electronics manufacturing industry.

### 3.2 Main problems

Although China's electronics manufacturing industry has considerably progressed, it continues to encounter numerous obstacles in its development [9]. Most core processes, high-end equipment, and manufacturing systems used in front-end manufacturing in China were principally established through foreign intervention. Moreover, China's electronics manufacturing industry encounters problems such as an unyielding technological blockade, strict equipment production controls, and lack of an international voice, hindering progress in this industry.

First, independent support for basic research in China is low. In the 20th century, China's economy was still relatively backward, and all core manufacturing equipment for first- and second-generation silicon-based semiconductor devices were imported, which significantly limited the development of China's chip and semiconductor equipment industry [10]. Developed countries had established deep theoretical foundations and long-term accumulation of technology through advanced industrial layouts and large-scale investments and were at the forefront of research and development. In recent years, China has made significant efforts to compete with developed countries; its electronics manufacturing equipment industry has developed rapidly, and numerous major breakthroughs have been achieved in several subfields. However, the major obstacles to the development of China's electronics manufacturing equipment industry are time constraints, small scale, insufficient accumulation of technological and talent reserves, insufficient independent investment in core technologies, and pressure from Western countries.

Second, the current mode of market competition in China hinders technological innovation. Because of the current scenario of the electronics manufacturing industry and China's relatively weak technological foundations, electronics manufacturing enterprises do not actively engage in the research or development of core technologies, and the homogenization of end products has resulted in intense competition, particularly on price. Many core technologies and high-end machines are foreign imports; domestic manufacturing enterprises often lack human resources, capital investment, and opportunities for market iteration, weakening the overall competitiveness of the market for China's domestically produced electronics manufacturing equipment (particularly high-end equipment) and its components. Opportunity for market iteration is the factor that most strongly affects technological

development. Therefore, to accelerate the development of domestically manufactured equipment, China must refine its approach and increase the competitiveness of its electronics manufacturing industry.

Third, electronics manufacturing equipment depends considerably on imports. The main bottleneck restricting the development of China's electronics manufacturing industry is the supply of high-end chips, high-end equipment, and key components. China is making significant efforts to expand its electronics manufacturing industry. However, while attempting to break through this bottleneck, it must focus on the problem of its dependence on imported equipment. To ensure the stability of its national economy and realize its manufacturing capabilities, China must overcome the long-term monopolization of high-end technologies by international leading companies, eliminate its dependence on imported electronics manufacturing equipment, and develop domestic high-end manufacturing equipment protected by independent intellectual property rights [11].

Fourth, China must make considerable progress before becoming an electronics manufacturing leader. In recent years, trade friction has frequently occurred between China and the United States, and the supply chain and ecology of the global electronics manufacturing industry have transformed. China's electronics manufacturing equipment industry has encountered several challenges. As a major contributor to electronics manufacturing, in addition to continuing to upgrade its front-end technologies, China has continuously developed its back-end electronics manufacturing equipment and key components, proposed a development strategy and implementation plan to address key technical problems, encouraged scientific and technological personnel and industrial enterprises to research and develop core technologies, and established independent control of this equipment and its key components. These measures have major strategic significance in ensuring the overall security of China's electronics manufacturing industry and supporting the growth of China's manufacturing power [12].

## 4 Development trends in the back-end electronics manufacturing equipment industry

### 4.1 Directions for technological development in the industry

In the post-Moore era, the increase in chip density has slowed, and chip device packaging manufacturing technology plays a key role in the development of the semiconductor industry. With the rapid development of 5G technology, high-definition displays, AI, supercomputers, modern military technologies, server central processing units, graphics processing units, mini- or micro-light-emitting diodes (LEDs), and other technologies, the back-end electronics manufacturing industry is pursuing the optimization of the cost–performance ratio, chip density, miniature and multilayer chips, multichip device integration, manufacturing precision, and acceleration of technological development. Therefore, the future goals of China's back-end electronics manufacturing equipment industry are high precision, high efficiency, and high integration [13–15].

With the miniaturization of chips and the increase in input/output density, the number of interconnection vias and density of multichip interconnection carrier substrate circuits have sharply increased. To prevent two-way interference and damage to dense circuits, requirements regarding the position and accuracy of microvia array processing or microstructure array cutting, the compactness of interconnection circuits, and the strength of the connection with the substrate have increased considerably. With the increase in the number of integrated chips, the line width, size, and distribution of the interconnecting apertures and, consequently, the line spacing and line thickness of the interconnected circuits have also increased considerably. In addition, owing to the pursuit of high consistency in multichip interconnections and high-quality transmission of high-frequency 5G signals, high-end substrates are increasingly created from hard and brittle materials, such as glass, which are difficult to process (but have favorable dielectric and conformal properties). These requirements are associated with considerable technical challenges related to the processing and manufacturing of high-density integrated multichip devices.

Over the past 20 years, researchers have identified numerous new relevant technical indicators, including the number of chips and integrated components per unit area or volume, miniaturization of the interconnected filling aperture/circuit line width and line distance, number of stacked layers of interconnected circuits, and decrease in production line time from days to hours. Therefore, the back-end electronics manufacturing industry urgently requires technological breakthroughs in core processes, equipment, and key components in many key areas, including high-precision and high-efficiency processing of interconnected microstructure arrays, packaging processes for dense and fine interconnected circuits, high-speed and high-precision device assembly processes, online precision detection systems, and structural optimization of high-speed manufacturing processes. The design and manufacturing of a high-speed precision motion platform and intelligent and flexible production line that adapts to variable and rapid manufacturing processes represent systematic solutions for highly precise, efficient, and flexible back-end electronics manufacturing technologies. Technological competition in this field will become

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increasingly intense, and the back-end electronics manufacturing equipment industry will adopt a new international focus.

### 4.2 Core technologies to be further researched and upgraded in China

This section describes the nine major categories of technology across 12 subfields that require further research: etching, polishing and thinning, wafer dicing and batch transfer, interconnect bonding, integrated packaging, substrate manufacturing, information and communication, component manufacturing, and testing. In its approach to factors ranging from the high-density integration of multichip stacked package devices to the manufacturing of electronic end products, the industry must continue to focus on basic research and strive to compete with or even surpass the international gold standard in terms of three technological indicators: high density, high precision, and high efficiency. Table 1 lists the 38 key technologies on which China's electronics manufacturing equipment industry must focus.

## 5 Developmental trajectory of China's back-end electronics manufacturing equipment industry: case analyses of typical enterprises

This section analyzes the developmental trajectories of four carefully selected representative enterprises in China to provide an accurate summary of the development status of China's back-end electronics manufacturing equipment industry. This summary can serve as a reference for other enterprises promoting high-quality development in this industry.

### 5.1 TCL Technology

TCL Technology was founded in 1981 as a home appliance business. Before its reorganization, TCL Technology had four listed companies: TCL Huaxing Optoelectronics Technology, KONE Electronics Holdings, Hanlinhui Information Industry, and TCL Electronics Holdings. TCL Huaxing Optoelectronics Technology, a major subsidiary of TCL Technology, was established in 2009 and primarily produces display modules.

The company's development strategy involves following the direction of international competition and prioritizing innovation and optimization of the layout of the industrial chain; it has established a relatively complete industrial chain system. The company's main products include non-bonding modules, embedded filters (on-cell), embedded liquid crystal touch screens (in-cell), and other bonding modules. To date, the company has focused on its internationally leading-edge thin and high-end in-cell bonding modules and has maintained a relatively complete front-end industrial layout. This company has the largest market shares of 8-K and 120-Hz high-end TV panels and 55-inch HD panels worldwide. In the 2018 ranking of enterprises by the number of US patents published by IFI Claims, Huaxing Optoelectronics ranked 53rd globally and third among enterprises in mainland China.

As a leader in the display panel industry, Huaxing Optoelectronics employs a development strategy based on adherence to its international vision, prioritization of technological innovation, and optimization of the layout of the industrial chain to facilitate the important connections that are not completely dependent on external suppliers and improve the company's industrial competitiveness and risk resistance.

### 5.2 Han's Laser Technology Industry

Han's Laser Technology Industry (hereinafter referred to as Han's Laser) is a manufacturer of laser processing equipment with the largest variety of products and highest performance in China. With the rapid development of China's electronics manufacturing industry, Han's Laser seized the opportunity to become involved in the manufacturing and processing of printed circuit boards, IC carrier boards, lithium batteries, LEDs, photovoltaics, panels, semiconductors, and 3C product assembly. It has proposed the Laser Plus strategy for both horizontal and vertical integration. Vertical integration based on this strategy involves promoting innovation in upstream core components such as lasers, engaging in industry–academia collaboration, and pursuing world-class production, whereas horizontal integration based on this strategy involves utilizing the opportunities for market iteration provided by the upgrading of China's electronics manufacturing industry and cultivating market competitiveness in the subfields. To date, numerous types of equipment for laser fine processing, such as machines for precision laser drilling, LED wafer dicing, panel terminal cutting, panel circuit repair, and mobile panel assembly lines, have attained international gold standards and have clear technological and market advantages in China. In addition, in the field of new energy, Han's Laser has successfully entered the industrial chain of Ningde Times New Energy

Technology and has continued to expand its reach to clients such as AVIC Lithium Battery Technology and Beijing Honeycomb Century Technology. Furthermore, the company has developed a systematic solution for the equipment used to cut, split, peel, and repair mini-LEDs. The company's share of the display panel industry has steadily increased. Semiconductors and photovoltaic equipment have successively entered the supply chains of leading enterprises, which is expected to enable rapid growth.

**Table 1.** Key back-end electronics manufacturing technologies requiring further research and development.

| Key areas | Research and development contents |
|---|---|
| Etching | Silicon substrate removal processes for silicon-based gallium nitride radio-frequency devices |
| | Wet etching processes and related equipment for third-generation semiconductor nanostructures |
| | High-precision and high-efficiency laser-induced etching processes and related equipment for glass substrates |
| Polishing and thinning | Chemical/electrochemical thinning and polishing technology for semiconductor wafers |
| | Key technologies and equipment for 7- to 14-nm chemical mechanical polishing |
| | Multiphysics-assisted, high-efficiency polishing technologies and related equipment for superhard third-generation semiconductor substrates |
| | Large wafers and ultra-precision thinning technologies and related equipment |
| Wafer dicing and massive transfer | Micro-LED laser mass transfer/repair processes and equipment |
| | Rapid laser composite cutting technologies and related equipment for silicon carbide chips |
| | Key technologies and equipment for automatic precision dicing of 12-inch wafers |
| Bonding | High-speed and high-density wire bonding technologies and related equipment for integrated semiconductors |
| | Multilayer silicon–silicon bonding and low-stress thinning and polishing equipment |
| | High-precision hot press flip-chip bonding technologies and related equipment |
| Packaging | High-density interconnection technologies for 3D chips |
| | High-temperature wire-free packaging technologies and related equipment for microelectromechanical system devices |
| | Ultra-micro and high-stability piezoelectric control dispensing technologies and related equipment |
| | High-density interconnection technologies for system-level packaging |
| | High-precision and high-efficiency chip fan-out packaging technologies and related equipment |
| | High-density wafer-level fan-out integration technologies |
| | High-power and high-pressure large-scale insulated gate bipolar transistors and related quality control technologies |
| Substrate manufacturing | Heterogeneous substrate preparation technologies and related equipment for through-glass via packaging |
| | High-density precision-interconnection substrate manufacturing technologies for flip-chip packaging |
| | High-performance ceramic substrate preparation technologies |
| | Phase-changed lead frames for ceramic substrate manufacturing technologies in integrated packaging |
| Information and communication | High-performance manufacturing processes and related equipment for optical communication devices |
| Key components | High-speed multiaxis long-stoke precision motion platform and related technologies |
| | Development and industrialization of ultra-low-mass particle vacuum gate valves |
| | High pumping speed-integrated ultravacuum magnetic levitation molecular pumps |
| | High-temperature thin-film vacuum gauges for etching or sub-atmospheric pressure chemical vapor deposition |
| Measurement and testing | High-density interconnect defect detection technologies and related equipment |
| | Contactless metal-film thickness measuring instruments |
| | Automatic optical inspection equipment for defects in the printing of organic LEDs |
| | Intelligent processing quality inspection equipment for indium tin oxide laser tubes |
| | 3D optical measurement technologies for silicon interconnection vias |
| | Online optical inspection equipment for nongraphic wafer defects |
| | Online defect detection technologies and related equipment for extreme ultraviolet lithography graphic wafers for 7-nm nodes |
| | High-precision capacitor coating technologies and localization equipment |
| | Screen driver chip solution processing technologies |

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In recent years, Han's Laser has achieved counter-trend growth, and back-end sales of products will reach 16 billion CNY in 2021, reflecting the extreme importance of prioritizing innovations in core technologies, actively integrating them into the market, and creating market iteration opportunities for electronics manufacturing equipment.

### 5.3 Shenzhen Liande Automatic Equipment

Shenzhen Liande Automatic Equipment (hereinafter referred to as "Liande Equipment") is a leading manufacturer of panel modules and has become involved in the manufacturing of automotive electronics, semiconductors, and other technologies in recent years. Since its establishment, Liande Equipment has employed a development strategy focused on optimizing flat-panel display automation equipment, remaining updated on advancements in industrial processing technology, accumulating deep technical reserves close to the market, optimizing the manufacturing process by engaging in value co-creation with customers, and strengthening its technological services. To date, Liande Equipment has collaborated with Foxconn, BOE Technology, Huawei Technology, Apple, Tianma Microelectronics, Lansi Technology, TCL Huaxing Optoelectronics Technology, Wuhu Changxin Technology, Lixun Precision Industry, and BYD. The company has also established strong cooperative relationships with many other modern leaders in the electronics manufacturing industry and has accumulated stable and high-quality customer resources. The company has identified the demand for upgrades in emerging electronics manufacturing fields such as the manufacturing of large-scale TV equipment, equipment to assemble OLED flat-panel display modules, automatic optical inspection equipment, automotive electronics, photovoltaic solar energy equipment, and semiconductor packaging equipment. Liande Equipment collaborates with customers to optimize production through value co-creation and has increased its investment in innovations in equipment digitization, automation, and intelligent design, as well as in the establishment of technological research and development teams. It has gradually formed a stable and sustainable technical-support platform based on its own resources. The company has won several major projects including contracts with Weixinuo, BOE Technology, and Chongqing Huike Jinyu Optoelectronics Technology. In the next two years, the company will expand production by establishing 150 to 200 large-scale display module manufacturing lines, and its overall market value is expected to reach 30 billion CNY.

The case of Liande Equipment demonstrates that focusing on the identified technological weaknesses in the industry and customer requirement for technological innovation and services is an effective strategy for promoting the growth of specialized, special, and new enterprises.

### 5.4 Beijing CETC

Founded in 1958, Beijing CETC is the predecessor to the Beijing Semiconductor Special Equipment Research Institute (the 45th Research Institute established by China Electronics Technology). It is a key national scientific research and production unit specializing in the research, development, production, and manufacturing of key processing technologies and complete equipment systems and the incorporation of electronic components into equipment. The unit utilizes its long-term accumulation of technological reserves and industry–academia collaboration to prioritize innovations in common technologies, remains updated on the requirements of the electronics manufacturing equipment industry, and focuses on fine optical machining, precision machinery, and system automation. Beijing CETC's primary subfields of interest are machine vision technology, motion control technology, precision motion workbench and material transmission system technology, and precision parts design optimization. Supported by key technologies, such as processing, physicochemical, and system integration technologies, Beijing CETC has developed eight other categories of processing equipment and products (electronics material processing, chip manufacturing, optical/acoustic/electrical testing, chemical processing, advanced packaging, electronic graphic printing, crystal components, and photovoltaic cells) and has focused on four main product types (ICs, photovoltaic components and modules, semiconductor lighting, and solar photovoltaic cells). In response to the demand for the advancement of China's electronics manufacturing industry, Beijing CETC is expected to achieve sustained and rapid growth in a new iteration of the development cycle of back-end electronics manufacturing equipment.

Beijing CETC's development strategy is based on utilizing the long-term accumulation of technologies developed by national research institutes to strengthen industry–academia collaboration and promote continual innovations in common technologies.

## 6 Case implications

Table 2 summarizes the key factors responsible for the success of these four enterprises. These factors have major implications for the development of China's electronics manufacturing equipment industry. Enterprises of all sizes must be innovation-driven, be integrated into the market, and strive to create market iteration opportunities for electronics manufacturing equipment. Leading manufacturers of electronic end products must focus on layout optimization and collaborative innovation across the entire industrial chain. Large leading equipment manufacturers must focus on the long-term accumulation of core technologies and the cultivation of core competitiveness in their subfields, and small- and medium-sized enterprises should promote technological innovation in the subfields and services closely related to the market to create value for customers. State-owned equipment enterprises should utilize the benefits of integrating national scientific research units, continually promoting innovations in common technologies, and actively integrating with the market.

**Table 2.** Key factors responsible for the success of the four enterprises.

| Case | Enterprise characteristics | Reasons for success |
|---|---|---|
| TCL Technology | Private enterprise (100 billion CNY level); international leader in the display panel industry | Adhering to the international perspective and attaching importance to the layout and development of the entire industrial chain; prioritizing technological innovation and emphasizing intellectual property rights |
| Han's Laser | Private enterprise (10 billion CNY level); industry leader in laser processing equipment | Utilizing the scale advantage of domestically manufactured end products, remaining close to the market, and actively creating market iteration opportunities for equipment; emphasizing long-term accumulation of core technologies and cultivation of competitiveness in subfields |
| Liande Equipment | Private enterprise (1 billion CNY level); specialized, innovative, and new enterprises in the field of panel module segmentation | Remaining close to the market, focus on market demand, and pursuing value cocreation with customers; prioritizing technological innovation in subfields and core competitiveness |
| Beijing CETC | The research institute was a restructured state-owned enterprise; leader in the semiconductor equipment industry | Relying on the support of national scientific research forces and engaging in industry–academic collaboration; prioritizing innovations in common technologies and actively integrating into the market |

### 6.1 Enterprise development

To promote the establishment of large-scale vertically integrated enterprises or inter-enterprise alliances throughout the industrial chain, China must first emphasize the leading role of major enterprises in addressing bottlenecks in the electronics manufacturing equipment industry. Second, China must support leading enterprises in key fields. A training base for key enterprises in the electronics manufacturing equipment industry must be established to address the core and key components within the industry, strong connections must be constructed between central and local governments, and hierarchical talent cultivation must be conducted at the provincial, municipal, and county levels. Third, China must support key enterprises to aid them in accelerating technological innovation and industrial development; deploy research and development centers, production bases, and marketing networks globally through domestic and foreign mergers and acquisitions, restructuring, and strategic cooperation; and expand into multinational companies with strong international competitiveness. Fourth, China must cultivate "unicorn" enterprises that can play a leading role in innovation and promoting the development of the new economy, thus encouraging the emergence of "individual champions" and specialized, special, and new enterprises in the industry.

### 6.2 Technological innovation

Innovation is the driving force of industrial development. Only by improving enterprises' ability to innovate and master independent intellectual property rights can China fundamentally improve the structure of its industrial chain, promote industrial collaboration to facilitate breakthroughs, and assist local industries achieve strong international competitiveness. First, cooperation within industrial chains must improve. The innovation chain must be arranged around the industrial chain. Second, enterprises must utilize system advantages and innovation cost advantages with the goal of supplementing, strengthening, and extending the industrial chain, focusing on technological weaknesses in the key components of the chain and conducting targeted research to gradually reduce technological dependence on Western countries. Third, China must promote and facilitate industry–academia

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collaboration, cultivate a mutually beneficial innovation ecosystem, improve the efficiency of scientific and technological breakthroughs, and accelerate the industrialization of technological innovation. Fourth, China must exploit the scale advantage of the domestic market while continually acquiring international innovations to encourage Chinese enterprises to accelerate innovation, optimize the layout of the entire industrial chain, and ensure the smooth circulation of domestically manufactured products in the international market during global market downturns.

### 6.3 Talent training

First, talent-training systems should be strengthened. The demand for talent in China's semiconductor industry is unfulfilled and the industry is undergoing a shortage of high-end talent and leaders. China must strengthen its talent-training systems to create an environment conducive to the emergence of talent in large numbers. Second, to support industrial development and cultivate active talent, leading international talent teams must be actively introduced and cultivated for various links in the industrial chain such as chip design, process development, equipment manufacturing, and sealing testing. Third, interdisciplinary and compound talent must be cultivated vigorously. Semiconductor manufacturing is a highly interdisciplinary technological field, and the current training model, which is based on excessive subdivision of majors at colleges and universities in China, must be abandoned. Optimizing the discipline layout and cultivating more compound talent with a solid background will further facilitate industrial development.

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