J. Microelectron. Manuf. **3**, 20030106 (2019)
doi: 10.33079/jomm.20030106

Editorial Introduction:

China's IC industry has been flourishing in recent years, huge market demand together with government investments are the major driving forces for this development. The status and development momentum of the Chinese IC industry also attracted wide interest and attention of international counterparts. A group of domestic IC experts are invited by the JoMM to write a series of articles about China's IC industry, including the history, current status, development, and related government policies. Information in these articles is all from public data from recent years. The purpose of these articles is to enhance mutual understanding between the Chinese domestic IC industry and international IC ecosystem.

Current Status of the Integrated Circuit Industry in China

— Overview of Semiconductor Materials Industry

1. Introduction of Semiconductor Material Market

1.1. International Situation

Material is one of the cornerstones of the semiconductor industry and the engine that drives innovation in integrated circuit technology. As shown in Figure 1, semiconductor materials are in the upstream of the entire semiconductor industry chain, which play an important role in the development of the semiconductor industry. It is characterized by large industrial scale, detailed industry division, high technical threshold and fast updating speed.

The semiconductor material industry is mainly divided into wafer manufacturing materials and packaging materials. According to SEMI, global semiconductor material sales in 2017 were $46.9 billion, increased by 9.6%. Sales of wafer manufacturing materials and packaging materials were US$27.8 billion and US$19.1 billion with year-on-year growth rates of 12.7% and 5.4%, respectively. In 2018, global semiconductor material sales reached US$51.9 billion, increased by 10.6% and exceeded the historical highest point of US$47.1 billion in 2011. Sales of wafer manufacturing materials and packaging materials were US$32.2 billion and US$19.7 billion with year-on-year growth rates of 15.9% and 3.0%, respectively.

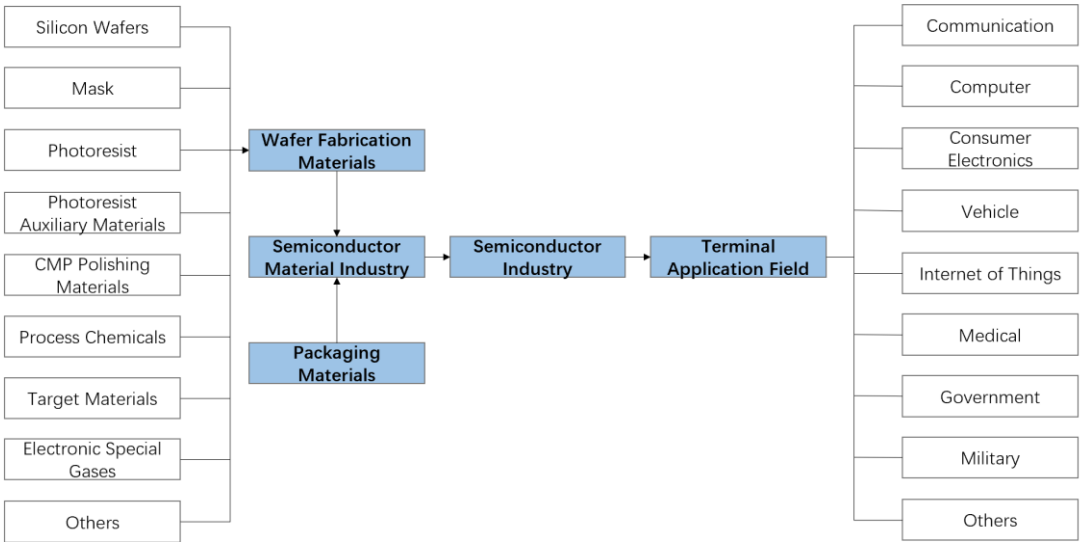

Figure 1. Material industry is an important support for the semiconductor industry.

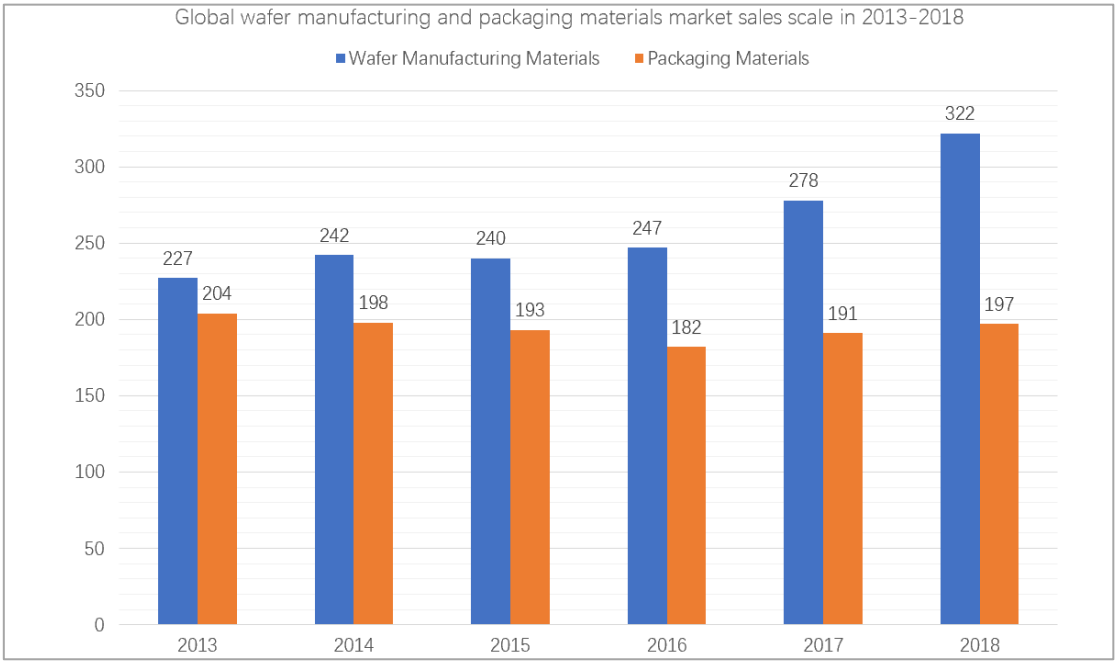

Figure 2. Global market sales scale of wafer manufacturing and packaging materials in recent years.

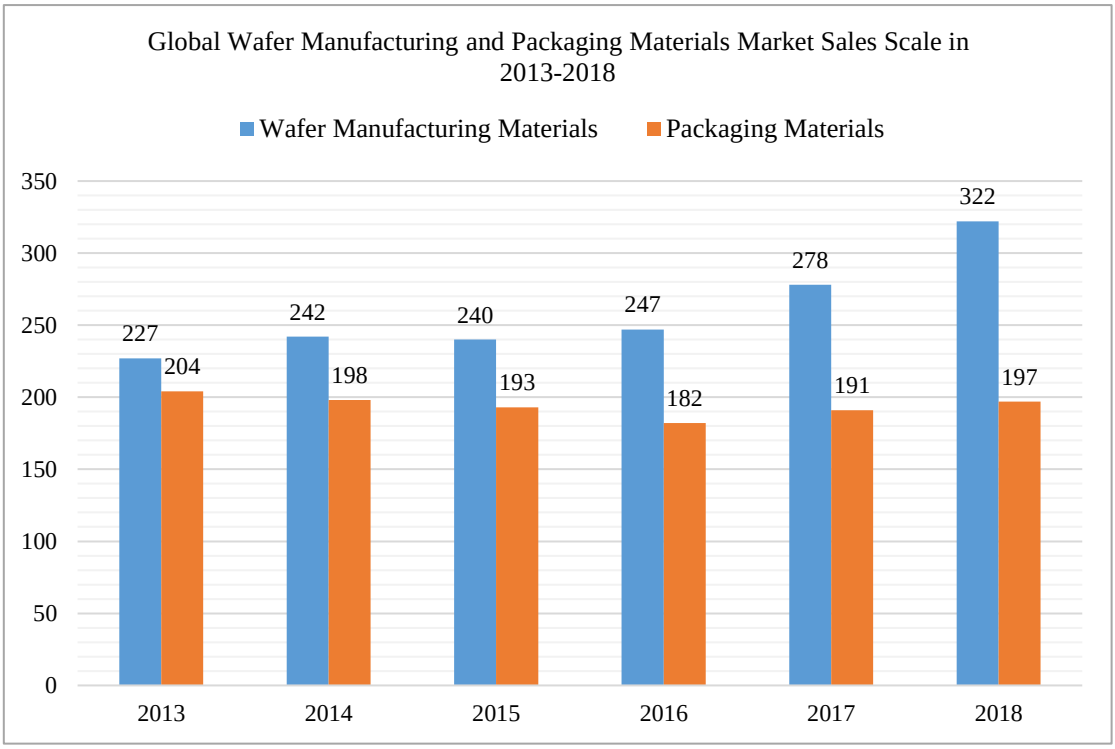

Figure 3. Global market scale of semiconductor and wafer manufacturing materials in 2013-2018.

In 2018, the global semiconductor wafer manufacturing materials market scale grew in tandem with the global semiconductor market. According to WSTS and SEMI statistics, the annual global semiconductor wafer manufacturing materials market in 2013-2018 accounts for about 7% of the global semiconductor market.

1.2. Domestic Situation

Semiconductor materials are mainly used in integrated circuits. In China, integrated circuits are mainly applied in computers, network communication, consumer electronics, automotive electronics, industrial control, etc. The total proportion of the top three accounts for 83%. In recent years, a series of policies aiming to promote the development of the IC industry were announced. For instance, the National Integrated Circuit Industry Investment Fund was founded in 2015, which rapidly promotes China's IC industry. In 2015, China's IC industry sales reached 360.98 billion yuan, with year-on-year growth rates of 19.7%; in 2016, China's IC industry sales reached 433.55 billion yuan, with year-on-year growth rates of 20.1%; in 2017, China's IC industry sales reached 541.13 billion yuan, with year-on-year growth rate of 24.8%; China's IC industry sales from January to September in 2018 reached 446.15 billion yuan, with year-on-year growth rates of 22.4%. It can be estimated that by 2020, China's semiconductor industry will maintain a growth rate of more than 20%.

In the field of semiconductor materials, due to the high technical barriers of high-end products and the lack of long-term R&D investment and domestic enterprises, China's semiconductor materials are mostly in the middle and low-end areas in the international division of labor. The high-end products market is mainly monopolized by a few international companies from such as Europe, the United States, Japan, South Korea and Taiwan. For example, the market share of the top six companies in the global market of silicon wafers is over 90%; the market share of the top five companies in the global market of photoresists is over 80%; and the market share of the top six companies in the global market of high-purity reagents is over 80%; the market share of the top seven companies in the global market of CMP materials is up to 90%.

Most domestic products have a low self-sufficiency rate of less than 30% and most of them are packaging materials with lower technical barriers. The proportion of localization in wafer manufacturing materials is even lower, mainly relying on imports. In addition, domestic semiconductor materials companies are concentrated on production lines below 6 inches, and only a few domestic manufacturers have established the 8-inch and 12-inch production line.

Category	Use	Related Companies	Domestic Market Share
Silicon Wafers	More than 95% semiconductor chips and devices worldwide are made by silicon based functional materials	GRINM Semiconductor Materials CO.,LTD. ; JRH QL Electronics ; NEXCHIP ; NANJING GUOSHENG; SHANGHAI SIMGUI; SHANGHAI ZING SEMI ;	Mainly 6-inch and below, a small amount of 8-inch, 12 inch mainly relies on import
Photoresist	Mainly used in processes such as development and etching to transfer the required fine patterns from the mask to the base substrate to be processed.	Beijing KEMPUR ; SUZHOU RUIHONG Electronic Chemicals CO.,LTD. ; PhiChem ; TRONLY	Main products are LCD and PCB, photoresist mainly relies on import, foreign-trade dependence over 80%
Gases & MO Sources	Widely used in thin film, etching, doping, vapor deposition and diffusion processes.	SUZHOU JINHGONG GAS ; GUANGDONG HUATE GAS ; DALIAN CREDIT CHEM ; ZHEJIANG JUHUA CO.,LTD. ; JIANGSU NATA CHEM	Foreign-trade dependence over 80%
CMP Polishing Liquid	Polishing of integrated circuits and VLSI	SHANGHAI XINANNA Technology CO.,LTD. ; ANJI MICROELECTRONICS ;	Localization rate below 10%
CMP Polishing Pad	Polishing of integrated circuits and VLSI	CHENGDU TIMESLIVES ; SANGLONG CO.,LTD.	Localization rate below 5%
Plating Solutions	Electroplate	SHANGHAI SINYANG CO.,LTD.	Small part of them can be replaced by domestic products
Ultra-pure Reagent	Key auxiliary material for large-scale integrated circuit manufacturing, mainly used for chip cleaning and etching.	JIANGYIN JIANGHUA MICROELECTRONICS MATERIALS CO.,LTD. ; SUZHOU JINGRUI ; SHANGHAI SINYANG CO.,LTD. ; KAISN ; ZHEJIANG HUAYI	Part of categories can be replaced by domestic products, localization rate about 30%
Sputtering Target Materials	Used for semiconductor sputtering	NINGBO KFMI ; GRINM Semiconductor Materials CO.,LTD. ;	Mainly rely on import

Figure 4. Localization of different types of semiconductor materials.

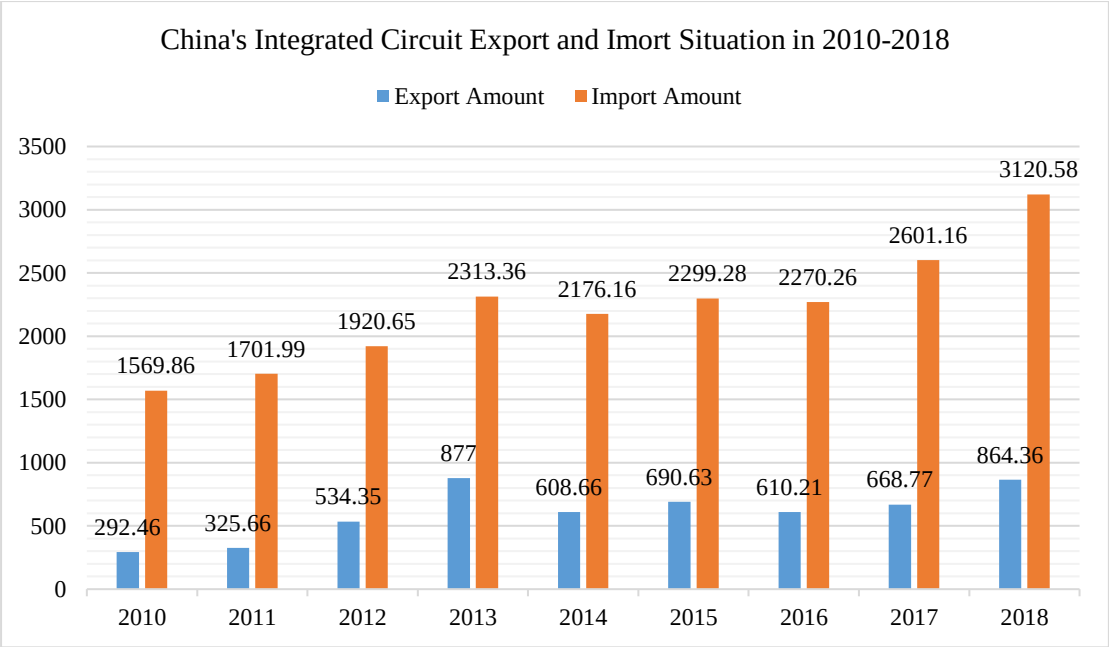

Figure 5. China's integrated circuit imports amounted to more than 200 billion US dollars, and the import substitution demand is large

Due to the huge demand and low self-sufficiency rate in China's semiconductor market, China's integrated circuit (commonly known as chip) imports are very huge. In recent years, the import amount of chips was stabilized at more than 200 billion US dollars every year. In the past decade China's chip imports have exceeded the amount of crude oil imports. For example, in 2018, China's chip import amount is 312.158 billion US dollars with year-on-year growth rate of 19.8%, while crude oil import amount is 240.262 billion US dollars. The chip remains on top among China's imported products and trade deficit has expanded year by year. In 2010, the trade deficit of integrated circuits was 127.74 billion US dollars. However, in 2017, the trade deficit of integrated circuits increased to 193.24 billion US dollars, and the trade deficit of integrated circuits in 2018 was 227.422 billion US dollars. Such a large trade deficit reflects the long-term serious shortage of China's integrated circuit market, and the market of import substitution is very potential.

2. Introduction of Domestic Semiconductor Materials Company

2.1 JRH QL Electronics

The company is the only semiconductor company in mainland China with a complete industrial chain of silicon single crystal ingots, silicon abrasive disc, silicon polishing disc, silicon epitaxial wafers and chip manufacturing. With a complete 4, 5, 6, and 8 inch silicon wafers product structure, it focuses on integrated circuits and discrete devices, lightly doped and heavily doped, polished and epitaxial wafers. With annual production capacity of nearly 8 million wafers, it is the largest semiconductor wafer manufacturing base in China. In 2010, the company led the national science and technology major project of “Very Large-scale Integrated Circuit Manufacturing Equipment and Complete Process”. The company passed the national acceptance check in May 2017 and officially has the large-scale industrialization capability of 8 inches of silicon wafers with a monthly output of 120,000 pieces which prove it has already mastered the core technology of 12-inch silicon wafers.

The company closely cooperates with Zhejiang University and builds a “Joint R&D Center”. In 2003, the company successfully cooperated with the National Key Laboratory of Silicon Materials of Zhejiang University to manufacture the first 12-inch nitrogen-doped silicon single crystal for VLSI with independent intellectual property rights. In 2009, it took the lead in breaking the situation that China's 8-inch silicon wafers were all depended on imports and sold 8-inch silicon wafers officially. Having several

core technologies and unique technical secrets with independent intellectual property rights, the company is a stable supplier of internationally renowned semiconductor companies such as ONSEMI, AOS, TOSHIBA and NXP, also one of the most important suppliers of major domestic semiconductor companies such as Hangzhou SILAN Micro, SMIC, HUAHONG Group and AVIC Microelectronics.

The company is the first batch of integrated circuit enterprises recognized by the National Development and Reform Commission, the Ministry of Finance, the Ministry of Industry and Information Technology, the General Administration of Customs and the State Administration of Taxation. It has also been recognized as a national innovative pilot enterprise, an innovative model enterprise in Zhejiang Province, and a provincial level R&D center, municipal academician workstation, municipal enterprise research institute, municipal technical innovation team, etc. Now it has become the leader of China's semiconductor silicon material industry and the backbone of the national semiconductor industry. The company has won the most influential companies in China's semiconductor support industry, the top ten semiconductor material companies in China, and China's top 50 companies in electronic materials industry. Relevant technologies and products won the first prize of Zhejiang Science and Technology, the first prize of Zhejiang Technology Invention, the China Semiconductor Innovation Product and Technology Award, and the Ministry of Industry and Information Technology Major Technology Invention Award.

2.2. Ningbo KFMI

Founded in 2005, Ningbo KFMI is a high-tech enterprise specializing in R&D, manufacturing and sales of ultra-high-purity metal sputtering targets. The company has undertaken national-level industrialization projects such as the National 02 Major Project and the 863 Major Project. It is the industry leader in high-purity sputtering targets in China. Its products include aluminum targets, titanium targets, tantalum targets, tungsten-titanium targets, mainly used in physical vapor deposition (PVD) for manufacturing VLSI, LCD panels, and thin film solar cells to make electronic film materials. The ultra-high-purity metal sputtering target developed by KFMI has filled China's blank in this field, ending the history of dependence on imports, meeting the expanding market demand of domestic enterprises and successfully acquiring world-class chip manufacturing. The company has broken the monopoly of US and Japanese and becomes a domestic force in the field of electronic materials. At present, KFMI' sales network covers Europe, North America and Asia. It supplies products to many international companies include TSMC, UMC, GF, SMIC, SONY, BOE, HUAXING Optoelectronics, SUNPOWER and other well-known semiconductors, panel and solar cell manufacturing companies.

The target products are recognized by TSMC because of the excellent quality. The company has established a partnership with TSMC since 2009 and continues to supply targets to TSMC's 6-inch, 8-inch and 12-inch wafer fabs. The company adheres to technological innovation and product upgrades and continues to supply high-quality semiconductor sputtering targets to TSMC. Based on excellent quality and service, and relying on close technical exchanges, KFMI and TSMC have established a good strategic relationship of mutual trust. The company ranked firstly in the TSMC quality evaluation of target suppliers in the third quarter of 2017.

It is worthy to mention that KFMI’s localized CMP Pad won the first order. CMP polishing pads have the characteristics of long product verification cycle and foreign oligopoly. In 2016, the company cooperated with Cabot Microelectronics in the United States for CMP Pad project and successfully obtained the certification of local mainstream chip manufacturers. In November 2017, the company won the first domestic CMP polishing pad order.

2.3. Hysol Huawei Electronics Co., Ltd.

HYSOL HUAWEI Electronics Co., Ltd. is mainly engaged in the R&D, manufacturing and sales of semiconductor and large-scale integrated circuit packaging materials. The company is appointed as the national key high-tech enterprise and the National 863 Program Achievement Industrialization Base. The company has been the top ten foreign-invested enterprises and top 20 tax-paying enterprises in Lianyungang for many years, also it has national post-doctoral research stations and Jiangsu IC packaging materials engineering technology research center. It is currently the world's largest manufacturer of molding materials, mainly engaged in semiconductor and large-scale integrated circuit packaging materials, research and development, production and sales. After years of development, the company has mastered more than a dozen epoxy molding compound manufacturing technology and has comprehensive conditions for mass production. The company has

first-class molding plastic production and testing equipment. It has 13 production lines which cover more than 100 kinds of production used for semiconductor discrete devices, power devices, special devices, large-scale and ultra-large-scale integrated circuit packages. The company's domestic market share, which is 35%, is the highest in China and the third in the world.

2.4. GRIM Advanced Materials Co., Ltd.

GRIM Advanced Materials Co., Ltd.., owned by Beijing Nonferrous Metals Research Institute, is engaged in R&D and production of silicon semiconductor materials. The company is under the leadership of the State-owned Assets Supervision and Administration Commission. The company is mainly engaged in the production and operation of rare earth materials, high-purity materials and optoelectronic materials. The subsidiary company, GRIKIN, is one of the few companies in China that can produce metal targets. It gradually occupies the domestic integrated circuit 4-6-inche market and now it is entering the 8 inch and above production market. With the support of a series of national major science and technology projects, Grim Semiconductor has successfully developed the first 6-inch, 8-inch, 12-inch and 18-inch Czochralski monocrystalline silicon in China. Among them, the 12-inch Czochralski monocrystalline silicon was rated as one of the top ten scientific and technological progress in China in 1997. Since GRIM Advanced Materials was established in 1999, the company has focused on the research and industrialization of large-diameter monocrystalline silicon and polishing disc engineering technology, and mastered key engineering technologies such as large-diameter monocrystalline silicon growth, silicon wafer processing and crystal micro-defect control. The company has applied for more than 100 patents and formulated dozens of national and industrial standards. Its industrial scale and technology level are both in the leading position in China. It has already become one of the leading enterprises in the field of semiconductor silicon materials in China and made important contributions to the technological progress and industrial development of China's semiconductor monocrystalline silicon and polishing disc industry.

2.5. Shanghai SINYANG

The company's leading products include surface treatment of electronic chemicals and wafer copper plating, cleaning of electronic chemicals. Shanghai XINSHENG, a subsidiary of the company, is the only company in the Mainland with a 12-inch large-size wafer manufacturing capability. At present, the company has signed a purchase intention agreement with SMIC, Wuhan XMC and HLMC and the sales prospects are totally clear.

The company's main products can be widely used in semiconductor manufacturing and packaging. In the traditional packaging field, the company's wafer dicing blade products have gradually increased in volume since 2017 and have achieved profitability. In the field of semiconductor manufacturing, wafer chemicals continue to maintain rapid growth, and wafer chemicals have entered SMIC, Wuxi HYNIX, HUALI Microelectronics, TONGFU Microelectronics, WLCSP, CHANGJIAG Electronics Advanced Packaging and other customers. Among them, the chip copper interconnect electroplating liquid product has become the Baseline of SMIC's 28nm technology node, and the baseline of Wuxi Hynix's 32nm technology node; the copper process cleaning liquid and the aluminum process cleaning liquid for the wafer process are also started supplying separately. In addition, the company has been added into the list of qualified suppliers by Taiwan Semiconductor Manufacturing Company (TSMC) and now is under product verification. In the field of IC packaging substrates, Shanghai Sinyang's electroplated copper additive products are still supplied in small quantity. In addition, the wafer wet process equipment of Sinyang Silicon (Shanghai) Semiconductor Technology Co., Ltd., a subsidiary of the company, has entered SMIC and other customers.

2.6. Jiangyin JIANGHUA Microelectronics Materials Co. Ltd.

It is a leading science and technology enterprise in Wuxi, a national high-tech enterprise as well. It mainly produces ultra-clean high-purity reagents, photoresist, photoresist auxiliary reagents and other electronic chemicals. Specializing in the production of semiconductor (TR, IC), crystalline silicon solar (solar PV), FPD panel(TFT-LCD, CF, TP, OLED, PDP, etc.) and LED, silicon wafers, lithium batteries, photomagnetic and other electronic chemical used in manufacturing, JHM is one of the biggest supplier with great variety of goods. The production base of ultra-high-purity wet electronic chemicals with an annual output of 80,000 tons has reached the international level. All major production equipment and testing instruments have been imported from

abroad, and the product quality has reached the international advanced level. JHM has always been the preferred supplier of many well-known semiconductor, crystalline silicon solar, and large-size LCD manufacturers in China, and its products have been exported overseas.

2.7. ANJI MICROELECTRONICS

ANJI Microelectronics is an independent innovative high-tech microelectronic material company integrating R&D, production, sales and service. The company has different kinds of products, including a variety of chemical mechanical polishing fluids, cleaning fluids, three-dimensional packaging materials and related chemical solutions for the IC industry. The company was founded by Dr. Wang Shumin, a well-known international CMP polishing fluid experts. The company has a senior professional team, consists of experts from global well-known integrated circuit manufacturing and material companies. ANJI Microelectronics has developed series of products in the field of integrated circuit chemical mechanical polishing fluid, cleaning fluid and three-dimensional packaging materials, and has achieved mass production and commercialization. Since its establishment, Anji Microelectronics has submitted more than 700 domestic and foreign patent applications, among them more than 200 invention patents were authorized. The company has also been selected as "Shanghai Patent Model Enterprise", "Shanghai Intellectual Property Advantage Enterprise". Besides mainland's customers, ANJI Microelectronics also has customers in the United States, Europe, Singapore, Malaysia, Taiwan and other countries and regions. The company was rated as "the most concerned local semiconductor equipment and material company" by the International Semiconductor Equipment and Materials Association (SEMI) and was considered to be the fastest growing company in the field of CMP polishing materials by the semiconductor industry.

2.8. Nanjing GUOSHENG ELECTRONICS Co., LTD

The predecessor of Nanjing GUOSHENG Electronics Co., Ltd. was the Electronic Material Product Department of the No.55 Electronic Research Institute of the MII (Ministry of Information Industry), specializing in the research and development and mass production of semiconductor silicon epitaxial materials. The company has advanced equipment, with various types of epitaxial furnaces produced by companies such as LPE, Gemini, etc., which can meet the needs of different epitaxial parameters of customers; test instruments include CV tester, infrared thickness gauge, SRP(Spreading Resistance Profiling), Four-Point Probes tester, etc. The company's ultra-clean area reaches 400 square meters, and the highest cleanliness level is 10. The company's main products include silicon based / silicon-carbide based epitaxial wafers, which are widely used in integrated circuit chips and semiconductor discrete devices. As an excellent domestic silicon epitaxial and silicon carbide epitaxial production service provider, Nanjing GUOSHENG has an advanced epitaxial R&D and industrialization platform with complete testing and analysis methods, and the company's products cover all types of epitaxy from 4 to 8 inches. The capacity can reach 250,000 pieces per month (equivalent to 6 inches). Nanjing GUOSHENG owns more than 20 national invention patents, has presided and revised more than 20 national or industry standards in the field of semiconductor materials. The company has a provincial and municipal "semiconductor silicon epitaxial material engineering technology centers" and has undertaken more than 20 science and technology projects with core competitiveness in the field.

2.9. Tianjin ZHONGHUAN ADVANCED MATERIAL&TECHNOLOGY Co., Ltd.

Tianjin ZHONGHUAN Advanced Material & Technology Co., LTD. is a professional polishing wafer manufacturer, mainly engaged in the R&D and production of 6-inch and 8-inch fused silicon polishing sheets. The parent companies HUANOU Company and ZHONGHUAN Electronic Information Group are China's currently largest and the world's third largest fume silica and silicon wafer manufacturers, leading domestic high-end electronic product manufacturers and system integration service providers. The company is a science and technology enterprise with independent intellectual property rights, and has been committed to the research and development of high-end technology. In 2013, it was awarded the title of "100 New Enterprises in National High-tech Zones". The company has built the world's first 4-8-inch compatible full-automatic polishing sheet production line and owns the first-class purification plant with the highest purification level among domestic peers. The company's main products have the world's top three comprehensive strength, the foreign market share exceeds 18% and the domestic market share exceeds 80%.

Relying on its unique industrial chain advantages, continuous technological innovation capabilities and friendly business interfaces to further improve the industrial structure oriented by energy-saving products, the company is continuing to create maximum value for shareholders, partners, and employees, and realizing sustainable development.

References

[1] 十张图带你了解半导体材料行业
[2] 2017 年中国半导体材料十强企业
[3] http://www.zjjrh.com/gsgk.htm
[4]http://www.hysolhuawei.com.cn/plus/list.php?tid=2
[5] http://zhonghuan.e-eway.com/about.html