CHAPTER 2

CHINA'S SEMICONDUCTOR INDUSTRY

Michael Pecht, Weifeng Liu and David Hodges

BACKGROUND

Domestic demand for semiconductors, especially integrated circuits (ICs), is growing rapidly in China, stimulated by the development of information technology and advanced telecommunication infrastructures throughout the country, and by growing demand for common consumer products. Although it is difficult to gauge the exact number of ICs being imported, various estimates of China's semiconductor market (e.g., by Dataquest, the Japan Electronics Industries Association, and SEMI) indicate that the market size was about $5 to 7 billion in 1996 and $8 billion in 1997 [Lammers 1997, Koo 1997]. In 1999, chip sales in China totaled $8.6 billion, or about 5.9 percent of worldwide semiconductor revenues. Market researchers from Cahners In-Stat Group estimate that China's chip purchases will increase at a 33 percent annual rate from 1999 to 2003, pushing the country's semiconductor market to nearly $27 billion in the next three years, or 8.6 percent of the world market. It is expected that, by 2010, China will become the world's second largest market for semiconductors, next to the U.S. [Semiconductor Business News, 24 February 2000].

In contrast to the highly sophisticated production facilities of Korea and Taiwan, China's semiconductor industry still consists of relatively small-scale manufacturers with low productivity and low-level process technology. In fact, the semiconductor manufacturing sector is the weakest link of China's electronics industry; 95 percent of the electronic products produced in China are in some way or another dependent on semiconductor components imported from the U.S. and Japan.

China's wafer fabs generally only have the capability to commercially produce 5- and 6-inch wafers with 0.5 to 1.6 μm line widths. They currently produce less than one percent of global chip production, meeting only 20 percent of domestic demand, far short of what is needed [Johnson 1999a]. Clearly, predictions that China will account for 15 percent of the total Asian demand for semiconductors, with projected annual sales of over $2 billion [Simon 1996] will not be realized.

The poor infrastructure, poor economic system and long supply chains for raw materials and manufacturing equipment contribute to inefficiency in the industry. Ongoing inability to transform technology into commercial success impedes shifting from R&D to production and marketing. Technology export control from developed countries blocks China's efforts to import advanced manufacturing equipment and to upgrade wafer-processing technology.

Despite limitations, China's semiconductor industry is expanding rapidly. From 1994 to 1997, the average growth rate of China's IC production was more than 60 percent. In 1998, China produced 1.5 billion ICs, an increase of more than 25 percent over 1997 [China's Electronics Industry Yearbook, 1999]. In 1999, China's IC production amounted to 2.3 billion, over 50 percent more than that of 1998 [Xinhua News, 3 May 2000].

INTEGRATED CIRCUITS

China's IC industry was virtually nonexistent before 1980. In 1996, China produced less than one percent of the world's ICs. But the strength of the country's growing electronics sector —already a major exporter —assures a ready market for any suitable IC that Chinese wafer fabrication plants can produce. Help for this budding semiconductor industry is coming from global companies such as Motorola, NEC, Mitsubishi, STMicroelectronics, Philips, Siemens, and Toshiba. These companies are transferring technology, investing capital, building wafer fabs, and forming joint ventures with Chinese partners.

Government Goals for China's IC Industry

During China's Eighth Five-Year Plan (FYP) period (1991-1995), the electronics industry experienced rapid increases in production and technology capability, output, and international trade volume. By the end of the Eighth FYP, the total output of China's electronics industry reached $30 billion [Schumann 1997]. However, the output of integrated circuits was far from meeting the ever-increasing demand of the electronics industry. In its Ninth FYP (1996-2000), the Chinese government was anxious to further increase the production capability of its domestic IC industry. China's government expressed its goals for IC production in broad terms [Schumann 1997]:

- reach large-scale production levels for 6 inch and 0.8 μm process technology;
- enter industrial production for 0.5 μm and 8 inch wafer technology;
- increase IC design capability to meet market demands;
- pursue R&D in 0.3 to 0.4 μm and advanced packaging technology;
- develop 8 inch, single-crystal wafer technology and begin domestic production.

In pursuing these goals, China had to rely on foreign technological know-how, while at the same time taking steps to protect its large market from foreign domination. Therefore, many restrictions were imposed on China-foreign joint ventures, as well as on wholly-owned foreign enterprises, to guarantee a certain level of technology transfer to China and to dedicate a significant portion of output for export.

Project 909

As a major part of China's Ninth FYP, to encourage domestic IC production capability and to reduce reliance on semiconductor imports, in 1995 China launched its largest ever IC development project in the Pudong New Area of Shanghai. With an investment of more than $1.2 billion, this project is the largest project ever undertaken in China's electronics industry. The Pudong Microelectronics Center enterprise is just one piece of a larger project known as Project 909, sponsored by China's Ministry of Electronics Industries (MEI), which merged in 1998 with the Ministry of Posts and Communications to become the new Ministry of Information Industries). The project calls for the establishment of five major IC production companies and as many as 20 design and development centers by 2000 [Johnson 1999b]. Its primary targets in semiconductors are to develop advanced 0.3 μm chip technology in labs; produce 0.5 μm chips on a trial basis, and mass-produce less sophisticated 0.8 μm chips, with a production goal of 1.2 billion units in the year 2000 and gross sales reaching 10 billion yuan ($1.2 billion). Shanghai was chosen as the site for the project because it had become the center for microelectronics production in China. In 1995, Shanghai plants accounted for 21 percent of total Chinese production of semiconductors [Simon 1996]. Project 909 started with the development of an 8-inch 0.35 µm wafer manufacturing facility in a joint venture between Huahong Group and NEC of Japan. Production began in March 1999 and one year later reached 10,000 wafers per month. Output, primarily DRAM memory chips, is exported back by NEC to Japan markets. Plans for several other manufacturing facilities with similar technological capability have not yet come to fruition. The limitation has been unavailability of large capital investments under terms that would maintain a large degree of Chinese control. The ultimate goal of Project 909 is to bring 0.35µm very large-scale integrated circuit (VLSI) technology to bear on telecommunication and comp uter-use ICs for both Chinese and export markets. [Lammers 1997].

IC Production and Market Size

China's total output in IC products reached close to 760 million units in 1996, which accounted for less than 0.5 percent of total world production [Weng 1996]. In terms of technological sophistication, China first applied 5 µm process technology, which was the technological level in the U.S. and Japan during the early 1970s, to manufacture IC products in 1986. In 1994, China was able to improve its IC mass production process capability to 3 µm, which was applied to two MOS LSI production facilities in Hua Jing Electronics Group [Weng 1996].

In 1995, the Chinese Government approved a total of 150 million yuan ($257 million) to build several VLSI plants. Of this, 1.4 billion yuan ($168 million) was spent for Hua Jing to construct a single 0.8 ~ 1.0 µm VLSI product line. The monthly output capacity was expected to be ten thousand pieces of 6-inch wafer and more than fifty varieties of IC products [Weng 1996]. In 1997, of some three thousand different kinds of IC products, most were small-scale ICs using 0.8 µm processing technology, which satisfied about 10 percent of total domestic demands. The technology in 1997 was 0.8 µm on 4, 5, and 6-inch wafers. The Chinese Government is seeking business partners from industrialized nations for transferring 0.5 µm (and smaller) and 8-inch (and bigger) semiconductor manufacturing technology.

Despite rapid increases in production capacity and technological sophistication, China's IC production is unable to meet domestic demand. Imports accounted for two-thirds to four-fifths of China's needed ICs. LSI and VLSI products are almost entirely dependent on imports. The Chinese Government continues to make great efforts to increase the local production of ICs and reduce the dependence on importing IC products.

Tables 2-1, 2-2 and 2-3 display China's growth in domestic IC demand and production, as well as the status of IC import and export. Figure 2.1 breaks down China's semiconductor market by type of application. Color TV was the largest user of IC products; however, the percentage has dropped from 33 percent in 1992 to 27 percent in 1995. In 2000, it is expected that consumer products will account for 28.7 percent of China's IC market, 19.4 percent for telecom products and 18.9 percent for PCs and their peripheral products [Asia Pulse, 17 March 2000]. Besides PC and telecom products, the market for IC cards has shown tremendous development. IC cards were first introduced in China in 1995, and are mainly used in public telephone, bank, parking lot, purchase and personal ID. Their use is continuously increasing. More than 80 million IC cards were issued in 1998, a 200 percent increase over 1997. The total number of IC cards in circulation in 1999 was expected to exceed 150 million [Liu 1999a]. By the year 2000, it is expected that Chinese people will buy more than 250 million IC cards for use in 700,000 public telephones across the country, making it the largest IC card market in the world [Asia Pulse, 31 May 1999].

Table 2-1: Total IC Demand and Production in China (million units)

Year	Total IC Demand[1]	China's Total IC Output[2]	IC Demand Met from Domestic Production (%)	Total Output of IC Products & Chips[3]
1993	850	178	21	180
1994	1,000	245	24	250
1995	1,500	515	33	786
1996	2,200	758	34	1,149
1997*	2,800	800	29	N/A
2000 (forecasted)	4,200	2,000	~50	2,500

* Estimated

1. SEMI® estimates, Weng 1996 and CEInet China IT Market Report 1997. 2. China Electronics Industry Yearbook 1997, p.146. 3. CEInet China IT Market Report 1997.

Table 2-2: China's IC* Import and Export Markets

Year	Import Units (billion)	Export Units (billion)	Import Value ($billion)	Export Value ($billion)
1995	5.9	0.9	2.2	0.37
1996	6.9	1.3	2.7	0.60
1997	9.6	2.5	3.5	0.86
1998	11.6	3.2	4.5	0.94

Including microelectronics components

Source: China Electronics Industry Yearbook 1997, p. 147, 1999, p. 211.

Table 2.3 China's IC Import and Export Product Type in 1999

Type	Import Volume (10 thousand)	Import Amount (10 thousand US $)	Export Volume (10 thousand)	Export Amount (10 thousand US $)
IC chip	4431	6798	1322	2277
MOS Technology Produce IC	52053	34535	1231163	31062
Bi-pole Technology Produce IC	13858	8013	8723	2258
Mix and other Technology Produce IC	285624	163831	56827	13856
Other Single Chip IC	1238718	393099	187667	55445
Mix IC	104676	134288	25619	70257

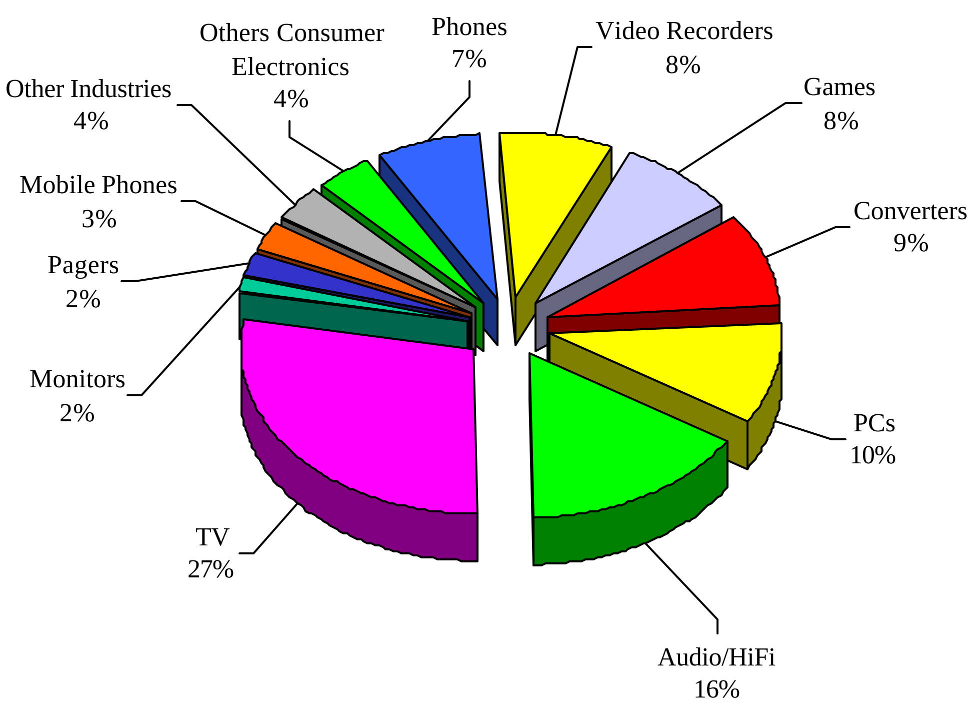
Microelectronics component	28684	12791	15302	13774
Total	1728046	753355	418576	188929

Source: Xiaotian Xu, Department of Electronics Information Product Management, Ministry of Information Industry, China, Date: 06/21/00

IC Design and Test

Until 1995 IC design was solely conducted within selected universities and research institutes. Fudan University in Shanghai, and Tsinghua University and Peking University in Beijing are some of the many institutions that actively support China's IC industry in design and testing. In 1986, the China IC Design Center (CIDC) was founded in Beijing as a state-owned enterprise. Its focus is primarily on ICCAD tools and IC design. It has contract fabrication capabilities with foundry partners from the United States, Japan, Singapore, Hong Kong and Taiwan. The center has successfully designed an 8 bit CPU (CIU9102) for smart cards. It is the first smart card integrated circuit with wholly-owned intellectual property. The product was designed using 0.8 μm CMOS technology [China Electronics Industry Yearbook, 1999]. In 1998, the center began to develop MP3 decoders. Now the chips for MP3 decoders are in mass production. The Panda system, developed by the center, is the first complete VLSI CAD system. Seven versions have been released. A new EDA system, Panda 2000, was released in 1997 (version 1.0). The current version (4/2000) is 2.2. Panda 2000 provides a series of tools for high-level design, layout, verification, and layout migration. Capabilities of Panda 2.2 are claimed to be similar to those of the suite of VLSI design tools sold by Cadence Design Systems.

Figure 2-1: Breakdown of Chinese IC Applications



CIDC has advanced capabilities for testing mixed signals as well as analog and digital VLSI. It has purchased the Teradyne A580 mixed signal test system, the Electroglas EG2001CX automated wafer prober, and TSSI TDS software for design-to-test linking. In combination, these tools enable CIDC to do thorough prototype testing, as well as production testing on a limited scale.

With government support, CIDC has established itself as a leader in IC design and provides ongoing technical support to seven regional IC design centers. According to CIDC, non-Chinese customers for design services or Panda 2000 tools include C-Cubed, S3, Intel, National Semiconductor, Fujitsu, and NEC. CIDC has 180 employees with over 60 percent of its engineers having worked or been trained abroad [CIDC 2000]. Its revenues in 1999 were $6 million; projected revenues in 2000 are $10 million. CIDC is believed to be seeking approval to privatize through a public stock offering.

Another national design base is the National Engineering Center for ASIC Design (NECFAD) in Beijing. It was previously the Microelectronics Design Center of the Institute of Automation, Chinese Academy of Sciences. Its primary focus is on developing IC analysis tools, technologies and systems. An IC analysis system (versions 1.0 and 2.0) has been developed by the center. A more advanced analysis system is now under development, which can automatically analyze sub micron and deep-sub micron integrated circuits. The new system is planned to be released at the end of this year [NECFAD 2000].

As of 1998, there were Chinese claims of more than one hundred design houses and about one thousand experienced IC design engineers. According to a survey by the China IC-CAD Federation, about 26 percent of the design houses are independent IC design centers, 33 percent focus on connection technologies with universities and institutes, 12 percent belong to semiconductor facilities, 14 percent are subsidiaries of system assemblers, and the remaining 15 percent are new IC design houses created by foreign or Taiwanese investors [Liu 1998]. For example, as early as 1995, Shougang NEC in Beijing was sending its engineers to design ICs at NEC’s facilities in Japan. Shanghai Belling has about thirty engineers designing ICs in-house, with a goal of fifteen to twenty new designs each year.

As market demand for IC products has increased, China‘s IC design industry is gathering government support and foreign investment. “Fabless” design is considered appropriate for China’s IC industry by out-sourcing fabrication. Project “909” calls for the establishment of as many as 20 design and development centers by the year 2000. More than US $100 million was invested to create an IC design community in China. Shanghai Hua Hong Group has established design centers in Beijing, Shanghai, Suzhou, Shenzhen and even in the U.S.’s Silicon Valley in order to recruit excellent local experts and catch up with the latest design trends and technologies. On December 28, 1998, Guo Wei Electronics Co. Ltd. was founded through the joint investment of State Development and Investment Corp. and Shenzhen Advanced Science Enterprise Group. The two invested more than $12 million in the joint project and shared equally the registered capital of $7.7 million (U.S). The company develops video frequency compressing products and 0.35-0.8 micron 8-inch silicon chips [CEInet 1998]. Shanghai Integrated Circuit Design Industrial Center (ICC) was opened in 2000 through the joint forces of China’s Ministry of Science and Technology and the Shanghai municipal government. It is the first Chinese industrial park dedicated to IC design [Liu 2000a]. The local government initially invested $12 million in the park’s construction, which includes more than 215,000 square feet of office space with low rents. ICC also offers amenities designed to attract startups, including facilities equipped with the latest tools, workstations and test equipment that can be rented at low cost. The center also offers design houses and universities a multi-project wafer-processing capability that handles many designs with similar processing equipment. The approach aims to reduce layout and foundry costs for the prototype and low-volume products developed by local designers. So far, thirteen design houses have moved to the center. Total IC and system revenues are projected to reach $250 million by 2005 [Liu 2000a]. Meanwhile, the Shanghai IC Design Research Center is under preparation.

The emergence of new design capabilities in China has created opportunities for foundries and EDA tool vendors. Leading U.S. EDA tool vendors have reported significant sales growth in China over these two years. CIDC alone claims to have spent about $2 million to license design tools from major U.S. supplies. Foundries including Hua Hong - NEC, CSMC - HJ and Hua Yue have provided their production services to local design houses, and are offering a variety of processing technologies together with tariff-free wafers. Meanwhile, local design houses are improving. CIDC (Beijing) has begun development of its own reuse tool at its Chinese and U.S. facilities. The development work is expected to yield Chinese-controlled intellectual property. Shenzhen State Microelectronics Co., Ltd., one of Hua Hong’s design houses, is developing an

MPEG-2 decoder and other IC designs. Hua Wei Technologies Co. Ltd, China's top telecommunication equipment manufacturer in Shenzhen, has developed a variety of advanced tools, and more than 160 engineers are working on ASICs. More than 10 ASIC designs have been used in Hua Wei systems [Liu 1999c].

Multinational companies are also making a concerted effort to enter the Chinese design market [Liu 1999d]. Intel, Motorola, Microchip, and NEC operate design houses in China. Microchips Technology Inc. plans to expand its presence in China by opening another three design centers in 2000, in Shenzhen, Chengdu and Fuzhou. Microchips is also planning to establish an Asian reference design center, possibly in Shenzhen [Leopold 2000]. By providing better benefits and higher salaries, these design firms are able to recruit excellent people. These companies also provide supporting and collaborate with universities and colleges on joint studies, and offer scholarships and education programs to college students - their future employees.

IC Technology and Product Development Status

Despite the rapid increase in production and technology, China's IC industry still lags far behind the technological levels of advanced countries. The Chinese Government is determined to push forward China's IC design and manufacturing capabilities through collaboration with global technology partners. Table 2.4 shows the status of IC technology development in China and several major technological cooperative ventures between foreign multinational corporations and domestic semiconductor companies in 2000.

In addition to cooperation with foreign partners to develop and transfer technologies, several organizations and research departments have been established over the years by government agencies and universities to advance domestic IC technology development and manufacturing capability. Table 2.5 presents eight research institutes and the corresponding IC technologies that are under development.

Table 2-4: IC Manufacturing Technology Status in China

Company (location)	Foreign Partner	Chinese Partner	Product Sector	Technology (monthly wafer capacity, in year 2000)
ASMC (Shanghai)	Philips Semi-conductors	Shanghai Belling	Wafer Foundry	5",1.5µm Bipolar (25,000) 6",0.6µm CMOS (15,000)
Shanghai Belling (Shanghai)	Alcatel (Belgium)	Shanghai Hua Hong/ Shanghai Bell Co.	Telecom IC Card Consumer	4", 1.2-2µm MOS 4", 3µm BiCMOS (total, 13,000)
Shougang-NEC (Beijing)	NEC (Japan)	Capital Iron & Steel Co.	4 Mbit DRAM, 64 Mbit DRAM, MCU	6", 0.35µm CMOS 6", 1.2µm MOS (total, 10,000)
Hua Jing (Wuxi)	-	State-owned	Consumer	4", 2-3µm Bipolar (15,000) 5", 2-3µm Bipolar (1,600) 5", 3µm MOS (10,000) 6", 0.6µm CMOS (10,000)
Hua Yue (Shaoxing)	-	Zhejiang Province	Consumer	3", 5µm Bipolar 4", 3-5µm Bipolar 5", 2 µm Bipolar
Shanghai Hua Hong NEC (Shanghai)	NEC (Japan)	Hua Hong Electronics	64 Mbit DRAM Logic IC	8", 0.35µm CMOS (16,000) 8", 0.35µm logic chips (4,000)
CSMC-Hua Jing (Wuxi)				-

Source: IEEE Spectrum, December 1995; D. Greene 1996; and Tsuda 1997; WSC study visit, 4/2000.

Table 2-5: IC Technology Development in China

Research Institution	IC Manufacturing Technologies R&D
Central Research Institute, Hua Jing Electronics Group Corp.	1µm (CSC245), IM MASK ROM, DSP high-speed digital signal processing circuit, 256K SRAM
Microelectronics Research Center, Tsinghua University	1~1.5µm VLSI, 1M ROM
47th Institute (Shenyang City), Ministry of Electronics Industry (MEI)	1.5µm
214 Institute, Weapon Industry Corp.	3µm ASIC
Microelectronics Research Center, Chinese Academy of Sciences (CAS)	0.8~1.2µm
ASC Shanghai Metallurgy Research Center	1µm

Microelectronics Technology Research and Training Center, Aerospace Industry Corp.	ASIC, GJB protocol microprocessing circuits
Institute of Microelectronics, Peking University	ASIC design, silic

Source: Summarized from Weng 1996.

Microanalysis

China's technical capability for microanalysis of materials and electronic devices is concentrated at the National Microanalysis Center (NMC) at Fudan University, Shanghai. The center occupies its own modern facility on the university campus. The center owns and operates state-of-the-art analytical instruments for all major forms of microanalysis:

- Electron microscopy
- Atomic force microscopy
- Secondary ion mass spectroscopy (SIMS)
- Auger spectroscopy
- X-ray analysis
- Chemical analysis
- De-layering of semiconductor devices
- Electrical analysis
- Device and integrated circuit analysis
- Failure analysis
- Reverse engineering of semiconductor products

The NMC has a substantial core budget from the national and city governments, but a growing fraction of its revenue comes via contracts with industry. During the study tour in April 2000, we were shown examples of analytical micrographs obtained using several of the above analytical tools. Clearly the staffs of NMC have excellent skills in utilization of these sophisticated instruments. One staff member was to be an invited speaker at a meeting on microanalysis at NIST this year.

We saw examples of work performed under contract in which VLSI semiconductor devices were analyzed to determine the steps of the process sequence used to manufacture the devices. This is a form of reverse engineering also practiced in other countries. Other examples were a part of failure analysis of semiconductor devices. Overall, our impression was that the technical capabilities available at NMC are very comparable to those found in the U.S., Japan, and Europe.

DOMESTIC SEMICONDUCTOR MANUFACTURERS

Of China's current total of 330 semiconductor plants, 36 produce ICs and the rest produce discrete devices. Among the 36 IC manufacturers, only a few do wafer processing and IC fabrication; most of them focus on electronic packaging and test. The IC fabrication companies include Shanghai Hua Hong Group Corp.; Shougang NEC, Beijing; Advanced Semiconductor Manufacturing Corp. (ASMC), Shanghai; Shanghai Belling Microelectronics Manufacturing Co. Ltd.; Hua Jing Electronics Group Co., Wuxi; and Hua Yue Microelectronics Co. Ltd.. Most of China's major semiconductor facilities are partly or wholly foreign-owned by companies such as NEC, Matsushita, SGS-Thomson, Philips, Northern Telecommunications, Samsung, Motorola, Harris, and Intel. China's state-of-the-art semiconductor technology at present is 0.35 μm with some still at a level of 2-3 μm, well behind the 0.18 μm or 0.13 μm of the West. Many advanced equipment makers are selling China their older machines for 1 to 1.5 μm specifications. Chinese facilities are making large deals to acquire foreign semiconductor manufacturing equipment, process software, and know-how for both common and state-of-the-art technologies. Although China's government is encouraging foreign investment as a means to hasten technology advancement, it is working on major projects to lessen its dependence on foreign chip suppliers. Several of China's largest and most advanced IC manufacturers are described below, in order of their founding (Table 2-6).

Hua Jing Electronics Group Corporation

Hua Jing Electronics Group Corporation is the largest of China's state-owned semiconductor plants and a subsidiary of China Electronics Corporation (CEC), a holding company that supports China's electronics industry. Hua Jing is located about 150 km west of Shanghai in the city of Wuxi in Jiangsu Province. It specializes in the R&D, wafer processing, packaging, and sales and marketing of two major categories of products: integrated circuits and discrete components. Hua Jing owns assets of $360 million and has 1,200 engineers, 380 senior engineers, 39 professional senior engineers and one academician of the Engineering Academy of China. Hua Jing was consecutively picked out as a key enterprise for government investment during the nation's sixth, seventh and eighth five-year-plan periods, and also listed as one of the 512 state-owned large or medium-sized mainstay enterprises.

Hua Jing began with China's purchase in the early 1980s of a turnkey, second-hand, 3-inch line from the United States. Its principal business is the development and manufacture of discrete devices and both bipolar and CMOS integrated circuits [IEEE 1995], primarily for television sets and audio equipment. The annual capacity of bipolar devices is 180,000 4-inch and 20,000 5-inch wafers with 2-3 μm and 70 million packages for assembly. As of early 1997, Hua Jing had started production of 6-inch CMOS wafers with 0.6 μm design rules, with an annual capacity of 120,000 wafers. It also processes 120,000 5-inch CMOS wafers with 3 μm technology annually. In addition to its IC manufacturing lines, Hua Jing produces almost all of its own silicon wafers and maintains an R&D center that develops and tests new process technology.

Table 2-6: Summary of Chinese IC Fabs

Manufacturers	Technology	Silicon Chip Size (inch)	Produce Capacity (per month)	Remarks
China Huajing Electronics Group Co.	2-5u (bi-pole)	4-5	15000	Including the pre- and post- produce lines
	1.5-3u (CMOS)	5	12000	
	0.8-1u(CMOA)	6	6000	
Huayue Microelectronics Co. Ltd.	2-5u (bi-pole)	4-5	20000	Including the pre- and post- produce lines
Shanghai Belling Stocking Co. Ltd.	1.2-2u (MOS)	4	15000	Including the pre-produce line
Shanghai Pioneer Semiconductor Produce Co. Ltd.	2-3u (bi-pole)	5	12000	Including the pre-produce line
	0.8u (CMOS)	6	6000	
Shougang NEC Electronics Co Ltd.	0.5-3u(CMOS)	6	8000	Including the pre- and post- produce lines

Shanghai Huahong NEC Electronics Co. Ltd.	0.35u(CMOS)	8	20000	Including the pre-produce line
Hangzhou Youwang Electronics Co. Ltd.	2-3u (bi-pole)	4	1800	Including the pre-produce line

Source: Xiaotian Xu, Department of Electronics Information Product Management, Ministry of Information Industry, China, June 21, 2000.

Hua Jing relies heavily on the international semiconductor community for its technology support. The technology for 125 mm-diameter wafers was obtained from Siemens AG of Germany [IEEE 1995]. Support for bipolar technology comes from Toshiba Corporation (Japan), and manufacturing software comes from Promis Systems (Canada), including the ~$0.5 million purchase in September 1996 of Promis' Manufacturing Executive System software. Technology transfer is also from AT&T, USA to construct the 6-inch wafer processing line as a part of the national "908" project [China Electronics Industry Yearbook, 1999]. In January 1998 Hua Jing completed a technology transfer from Lucent Technologies Microelectronics Group, which began in 1993 with an agreement between the State Council and Lucent, for worker training, processing technology, and related design tools for a 150 mm, 0.9 μm, single poly double metal complementary metal oxide semiconductor wafer [China Vista 1998]. The IC chips have been applied to the 5ESS systems made by Lucent's joint venture in Qingdao, Shangdong Province. According to a purchase contract signed recently, Lucent will also purchase telecom IC chips from Hua Jing [Asia Pulse, 3 April 2000]. Also, Intel has licensed Hua Jing as one of its testing and packaging partners for selected chips [Intel 1998].

Chinese authorities intend Hua Jing to be a "national champion" in the development of the country's semiconductor industry [Howell et al. 1995]. The Wuxi Hua Jing Expansion Project to upgrade the semiconductor manufacturing facilities and construct the IC research center was one of a handful of leading national projects considered to be essential to national development. The center has a Class 10 clean room that meets requirements for 0.8 μm ICs as well as those with 2 to 3 μm design rules.

In order to promote system innovation and corporation re-course, two subsidiary companies were founded in 2000. They are Wuxi Hua Jing Microelectronics Co. Ltd., and Wuxi Hua Jing - Gui Ke Microelectronics Co. Ltd. The primary business of the former will be front-end wafer processing of discrete and bipolar devices and production of silicon wafers. The company plans to issue A stocks in China in 2001. Hua Jing - Gui Ke was established mainly based on the Institute of Design and Test of the MOS Electronic Circuit Factory of the Group Corporation. Its business focuses on IC design and development. In September 1999, Hua Jing Group Corporation also issued a letter of intent to seek foreign partners for cooperation.

Shanghai Belling Stock Holding Co. Ltd.

Shanghai Belling Microelectronics Manufacturing Corporation was the first joint venture in semiconductor manufacturing in China. It was founded in September 1988 by Shanghai Electronics and Operation Instruments Holding Company, Radio Factory 14, and Shanghai Bell Telephone Equipment Manufacturing Company (itself a joint venture with Alcatel Bell, the Belgium branch of Alcatel). The total investment was $82.4 million [Belling 1996]. By 2000, the total assets of the company had reached $150 million. The company successfully issued stock in 1998, the first company in the IC industry to do so, and changed its name to Shanghai Belling Stock Holding Co. Ltd. Shanghai Hua Hong Group Co. Ltd. holds 38.45 percent of its shares and ranks the biggest shareholder of Shanghai Belling, followed by Shanghai Bell Co. with 25.64 percent of shares. For every year from 1994 to 1997, the company was rated as one of the top-500 foreign-invested enterprises and also one of the top-100 electronics enterprises in China. In 1999, Shanghai Belling 's revenue was $49 million.

Shanghai Belling is located in Cao He Jing, a well-established, high-technology development zone in southwestern Shanghai. It has over five hundred employees, about 40 percent of whom are engineers and technicians. The company uses a Western-style, team-oriented management structure rather than a Chinesestyle structure. Since its establishment, Shanghai Belling has built up three product categories: (1) specialized integrated circuits for telecommunications – each year up to ten million chips which support 5 to 6 million lines of exchange have been applied in China's fast-developing telecommunication network; (2) chips for IC cards; and (3) chips for intelligent control, including chips for electronic watt-hour meter, fuzzy logic MCU, etc. Most of Shanghai Belling's revenues come from ICs made for use in the private branch exchanges of Shanghai Bell Telephone, the first switch-maker in China to use locally made circuits [IEEE 1995]. The remainder comes from sales of micro-controllers and memory chips for use in such consumer products as appliances and remote control units for television sets and compact disk players. Shanghai Belling has independently designed and produced many kinds of IC card chips that have passed technical scrutiny. In 1999, with revenue for the 7442 IC card chips amounting to $3.2 million, Shanghai Belling became the first manufacturer in China to mass produce IC card chips and thus ended China's situation of wholly relying on imported IC card chips. At present, Shanghai Belling is developing IC card chips of higher technical level such as contact less cards and CPU cards. Moreover, in 1999 the revenue for its fuzzy logic MCU chips was $11.47 million, accounting for 90 percent of the domestic market. Shanghai Belling manages its quality system according to ISO 9001 standards.

Shanghai Belling Technical Center is a state-level enterprise technical center. The center was established in January 1995 and has been the leader in China's integrated circuit design field. The center is mainly responsible for marketing strategy studies, project scheduling, the design and development of new products, and research on new designing techniques, processing technologies and integrating techniques. Its major research and development covers the fields of integrated circuits for telecommunications systems, chips for IC cards and chips for intelligent consumer products, etc.

As of 1996, Shanghai Belling had one fabrication line, a 2000 m^2 Class 10 facility that annually produces over 160,000 1.2-3 μm bipolar and CMOS ICs on 100 mm (4 inch) wafers [Belling 1996]. Belling planned to upgrade its IC manufacturing technology to 6 inch, 0.8 μm by 1998 [Koo 1997.] and make ICs with 0.5 to 0.8 μm feature sizes on 200 mm (8 inch) wafers in the near future [IEEE 1995]. However, this project was cancelled by the company in 1999; instead, the company purchased 34 percent of stock shares of Shanghai Advanced Semiconductor Co. Ltd. for $17 million to promote its wafer processing capacity. The new plan will be fulfilled in 2000. Also, the company purchased 25.5 percent of the shares of Shanghai Hong Ri International Electronics Co. Ltd. for $1.6 million in order to improve its global sales network.

Advanced Semiconductor Manufacturing Corp. of Shanghai

Advanced Semiconductor Manufacturing Corporation of Shanghai (ASMC) was established in 1988 as a joint venture between Philips NV of the Netherlands and a group of Chinese investors. Northern Telecom, Ltd., (Nortel) of Canada joined the partnership in 1995, and its technology is the basis for ASMC's second line. However, Nortel dropped out of the partnership recently. ASMC, like Shanghai Belling, is situated in the Cao-He-Jing high technology park in southwestern Shanghai, which offers tax-free exports. The company draws most of its technical staffs from Fudan and Jiaotong Universities in Shanghai, two of China's premier universities. It employs over 450 people.

ASMC has two wafer fabrication lines. Fab I is a Class 10 fabrication plant able to process monthly 25,000 5-inch wafers for bipolar devices with a feature size of 1.5 μm. In 1997 ASMC processed more than 200,000 5-inch wafers and aimed to process about 250,000 in 1998. Fab II, which became operational in March 1997, is a Class 1 wafer fab able to process monthly 15,000 6-inch 0.6 μm CMOS wafers [ASMC 1998].

ASMC's product portfolio includes 3 μm bipolar, single/double metal bipolar devices up to 60V for TV and telephone applications; 3μm low-voltage (1.5-9V) CMOS with EEPROM option for telecom and consumer applications; 1 μm single poly/double metal and double poly/double metal CMOS devices; 1.2 μm single poly/single metal SMOS devices with EEPROM option; and 1.5 μm, 0.8 μm single poly/single metal CMOS devices [ASMC 1998]. ASMC started strictly as a foundry and did not sell ICs of its own design, servicing IC manufacturers whose own fabrication lines were at capacity, as well as so-called "fabless" semiconductor companies. Although this is still its primary market, it is working on coordinating design, assembly, and testing of its products. As proof of ASMC's growing status and capability in semiconductor manufacturing, it achieved ISO 9002 certification in January 1995, QS-9000 certification in February 1997, and it became the first ISO14001 certificated enterprise in the semiconductor manufacturing field in China in August 1998.

Hua Yue Microelectronics Corporation

Hua Yue is another state-owned semiconductor business controlled by CEC, but is less competitive. It sells its products on the merchant market and so is unlike either ASMC, which is a pure foundry, or Shanghai Belling, which sells most of its products to a single partner [IEEE 1995]. The company, located in the city of Shaoxing, manufactures bipolar ICs for television sets and telephones. In 1995-1996/7, Hua Yue started 15 to 17 thousand wafers with 3 to 5 µm feature sizes per month, of which seven thousand were 100 mm in diameter and the remainder were 75 mm [IEEE 1995, Koo 1997]. The company is expanding its capabilities to include 125 to 150 mm lines with 1.2 to 2 µm design rules that will enable it to produce ~50 million ICs per year [Howell et al. 1995, Tsuda 1997]. In 1998, Hua Yue purchased a 5-inch 2 µm bipolar manufacturing line from Fujitsu that is dedicated mostly to analog devices [Liu 1999d]. This line has been put into production, with the yield of the first two types of products over 90 percent [China Electronics Industry Yearbook, 1999]. Overall, Hua Yue has benefited less than Hua Jing from foreign technology, and has been searching unsuccessfully for a foreign partner [Koo 1997].

Shougang NEC Electronics Corporation

Shougang NEC, a joint venture of Japan's NEC Corporation and the Capital Iron and Steel Company of Beijing, was founded in Beijing in 1991. This company designs, fabricates, assembles, and tests a variety of ICs, including linear devices, memories, microprocessors, gate arrays, and communications chips. A new manufacturing plant, office, and dormitory building was completed in October 1993, assembly operations started in 1994, and wafer fabrication began in March 1995. The company employs over eight hundred persons, and most of the engineers are trained in Japan. As of 1996, the facility assembled a maximum of four million 16 Mbit DRAM units a month, and processed three to four thousand 6-inch, 1.2 µm wafers a month for 4Mbit DRAMs, MCUs, and other ICs, corresponding to forty-seven million units, well above original projections [Tsuda 1997]. Ramp-up to five to eight thousand wafers a month was achieved in December 1996 as planned [Lammers 1997]. NEC provides production and management technology, including advanced LSI circuit diffusion and packaging production lines and testing equipment. The Chinese share in the joint venture started at 60 percent and has decreased to 49 percent; NEC's stake in the joint venture has risen from 40 percent to 51 percent. Total first-phase investment was about $240 million for 4-bit micro-controllers as well as the 4 Mbit and 16 Mbit assembly operations. A further investment of over $100 million was made for the production of 0.5 µm devices for 16 Mbit DRAMs [Tsuda 1997, Lammers 1997]. The ICs produced by Shougang-NEC have been used in remote control for color TVs, in air conditioners, VCDs, IC cards, clocks, and palm PCs. Now Shougang-NEC supplies 50 percent of the ICs for the domestic color-TV remote controls and clocks markets.

In the third quarter of 1998, Shougang NEC introduced the first 64 Mbit DRAMs [China Economic Information Net IT News, 19 August 1998]. In 1999, Shougang NEC invested around $100 million to upgrade its wafer processing technology from 0.5µm to 0.35µm. Production volume is expected to increase from 8,000 wafers per month to 10,000 wafers per month. In 2001, monthly production volume will be raised to 15,000 wafers. Starting in 2000, Shougang NEC plans to construct an 8-inch 0.25µm wafer processing line, with a monthly capacity of 20,000 [Shougang, 2000]. This indicates that China has made progress over the years to improve and upgrade its products and technologies in order to reach the world's advanced standards.

NEWER FABS

China is pushing plans for construction of several sub micron fabrication facilities with support from the government and foreign companies. This section presents some of the recent major efforts in China.

Motorola

Motorola has been the largest U.S. investor in China. By the end of 1999, it had committed more than $1.5 billion in China. It has seven manufacturing operations in Tianjin and seven joint ventures in other parts of the country. With over $900 million in export recorded by the end of 1997, Motorola was the largest exporter among foreign manufacturers in China.

In 1995, Motorola began to construct a wholly-owned sub micron fab in Xianing, south of Tianjin city, at an estimated total cost of $1.2 billion. Under the plan, an 8-inch wafer-processing line was to be built to process devices with 0.8 µm technology in 1998 and 0.5 µm BiCMOS and CMOS technology in 1999. Monthly capacity was planned to reach about twelve thousand wafers per month. Major applications are telecommunications and automobile electronics [Tsuda 1997]. In May 1998, Motorola announced that would double the size of the Tianjin wafer-processing facility by spending $2.6 billion to turn the site into a "superfab" and a linchpin in its Asian operations. The Tianjin manufacturing complex was planned to contain both high-volume, front-end, wafer-fab lines and advanced back-end chip-assembly operations. The second phase of the production plan called for a 0.35 µm fab line to come on line in 2000, doubling the silicon-processing capability of the site [Robertson 1998a]. Motorola also announced plans to advance the project to 8-inch and 0.25 µm technology [Liu 2000b]. However, as of April 2000, it appears that the project has been delayed.

In 1998, Motorola launched an advanced materials joint research program to investigate fundamental properties of ferroelectric thin-film materials. This class of materials has potential application for advanced non-volatile memory for cellular phones and smart cards. The program will draw upon the technology strength of the National Lab of Solid State Microstructures at Nanjing University and the technology application capability of Motorola [Semiconductor Business News, 2 April 1998].

In October 1999, Motorola Semiconductor Products Sector announced plans to open a chip design center in Suzhou, Jiangsu Province, focusing on microprocessors and IC technology for consumer electronics and telecommunications [EE Times, 1999]. The designs from the Suzhou center will be produced at Motorola's fab in Austin, Texas, with some outsourcing of production to foundries in Taiwan and South Korea. The center has 20 local engineers, and plans to expand the number to over 80 at the end of 2000 [Liu 2000b]. In the same year, Motorola Semiconductor Products Sector opened the China Predictive Technology Laboratory (CPTL), a research and development operation that will model the behavior of advanced silicon processes and systems in order to reduce cycle time to the customer. The laboratory is located at the Motorola North Asia Center, Beijing.

On November 3, 1999, Motorola Research Institute (China) was founded. It includes 18 R&D centers across China (including Hong Kong), and 650 researchers. The annual R&D funding amounts to $150 million. Research areas include advanced semiconductors, micro controllers, CDMA and the "Will System," and software development [Huang Jing Reports, 4 April 2000].

Shanghai Hua Hong (Group) Co., Ltd.

Shanghai Hua Hong (Group) Co., Ltd. was founded by China Electronics Company (CEC), Shanghai Jiushi Company, and Shanghai Instruments Group in 1996. Now Shanghai Hua Hong owns six wholly-owned or stock-holding subsidiaries. They are Shanghai Hua Hong NEC Electronics Co. Ltd., Beijing Hua Hong IC Design Co. Ltd., Shanghai Hua Hong IC Co. Ltd., Shanghai Hua Hong International (USA) Co. Ltd., Shanghai Hong Ri International Electronics Co. Ltd., and Shanghai Hua Hong-Ji Tong Smart Card System Co. Ltd [Shanghai Hua Hong 2000].

Shanghai Hong Ri International Electronics Co., Ltd. was established in coordination with one of the nation's most significant projects, Project 909. Hong Ri is a joint venture funded by Shanghai Hua Hong (Group) Co., Ltd. and Tomen Japan, which undertakes the task of obtaining wafer processing orders for Hua Hong and expands both domestic and overseas markets for Hua Hong Products.

Shanghai Hua Hong International (USA) Co., Ltd. was established in 1997 in Silicon Valley, with registered capital of $3 million. The major business of Hua Hong International (USA) Co., Ltd. is to provide not only overseas processing orders for the integrated circuit production line of Hua Hong Group, but also to take advantages of its Silicon Valley location to collect information on market trends and international IC technology. Hua Hong International (USA) Co., Ltd. also participates in some venture capital projects. In December 1997, the company invested $1.5 million to co-establish American New Wave Semiconductor Co., Ltd.

Shanghai Hua Hong - Ji Tong Smart Card System Co., Ltd. was established on the basis of Shanghai Ji Tong Smart Card System Co., Ltd., funded by Shanghai Hua Hong (Group) Co., Ltd. Hua Hong - Ji Tong mainly deals with the research, designation, and manufacture of IC card systems and IC reading devices.

Shanghai Hua Hong NEC Electronics Co. Ltd. was jointly funded by Shanghai Hua Hong (Group) Co., Ltd. and Nippon Electronics Co., Ltd. (NEC). Hua Hong NEC was established on July 17, 1997, with registered capital of $700 million and a sharing period of 20 years. As a vital step in the Chinese Government's ninth FYP Project 909 to establish an advanced semiconductor industry in China, it selected NEC in October 1996 as a joint venture partner with Chinese partners to design, manufacture, and market memory and logic semiconductors using 0.5 to 0.35 μm process technologies [NEC 1997]. The Hua Hong plant is 93,700 square meters in area, of which 62,000 square meters are for plant construction, and 5,000 square meters are for clean processing. The fab was built in Pudong, Shanghai, for a total investment of about $1.2 billion. NEC holds 28.6 percent of the total, and Shanghai Hua Hong Group Co., Ltd.'s share is 71.4 percent. Employees were planned to number five hundred in 1999 and seven hundred by 2001. The fab started production at the beginning of 1999 with a capacity of 10,000 8-inch wafers a month for memory and logic ICs. The capacity will be doubled in 2000, among them 64-Mbit DRAMs will comprise 16,000 wafers per month, with 4,000 wafers devoted to logic chips for handheld cell phones and PDAs. All of the DRAMs are to be exported to Japan. At the end of 2000, the joint-venture operation will be upgraded to 0.25 μm processing equipment from 0.35 μm, enabling the fab to produce 128-Mbit DRAMs. NEC Corp. has received permission from the Japanese Government for the upgrade [Robertson 2000]. As part of the agreement, NEC is establishing a working partnership with MEI through which NEC can enter into other businesses in China, but must also negotiate financial and management arrangements such as product mix, where disagreements exist between the Chinese and Japanese investors.

Beijing Hua Hong IC Design Co., Ltd. was established in February 1998 between Beijing Electronic Information Industry (Group) Co., Ltd. and Shanghai Hua Hong (Group) Co. Ltd. with registered capital of $18 million. The company undertakes contract design work for computer ICs, telecommunication ICs, consumer products ICs or special ICs, and system level ICs from both domestic and overseas customers. In order to learn the advanced experiences in integrated circuit manufacture and management from developed countries, and to expand its overseas market, Beijing Hua Hong IC Design Co., Ltd. has shared the investment of $30 million with NEC to establish Beijing NEC IC Design Co., Ltd. Sixty percent of the overall investment in the company is owned by NEC and its affiliates, including Shougang NEC [Williams 1998]. The Beijing NEC IC Design Co., Ltd. aims to provide Project 909 with two hundred kinds of ICs and twenty thousand units of 8-inch silicon chips by 2001 [China Economic Information Net IT News, 11 September 1998]. It will focus on designing microcomputers, ASICs, IC cards, and other semiconductor products for use in applications in the areas of digital video and still cameras, consumer electronics, and mobile communications equipment. In addition, system on chip (SOC) devices will also be designed by the joint venture. Devices designed by the company will be produced at Shougang NEC or Shanghai Hua Hong NEC.

Shanghai Hua Hong IC Co., Ltd. is a research and design company for integrated circuit products, funded by Shanghai Hua Hong (Group) Co., Ltd., Shanghai Institute of Metallurgy Research, and Fudan University. The registered capital of the company is $12 million. Equipped with advanced integrated circuit computer-aided design (ICCAD) instruments, the company mainly deals with research and design for several advanced integrated circuit products including IC card chipsets, chipsets for telecommunication products, and MCU for consumer products in coordination of Project 909's production line.

CSMC-Hua Jing

WuXi CSMC-Hua Jing Co., Ltd. is a joint venture between Central Semiconductor Manufacturing Co., Ltd. (CSMC) and Hua Jing Electronics Group Corp. It was established on August 1, 1999 and located at Wuxi National Hi-Tech Industrial Development Zone. CSMC holds 51% of the equity and Hua Jing holds the other 49%. The joint venture leases facilities and equipment of Hua Jing’s MOS wafer fabrication for MOS wafer foundry service [CSMC-Hua Jing 1999].

CSMC - Hua Jing provides both 5-inch and 6-inch wafer foundry service for the worldwide IC design centers and IDMs. It has a Class 10 clean room with an area of 3,400 square meters. The maximum throughput per month is 14,000 5-inch wafers and 8,000 6-inch wafers with 0.5 µm technology. During 1999, CSMC-Hua Jing intended to double the maximum throughput after resolving some equipment bottlenecks. The company had 279 employees (Mid-year 1999). Most of its key managers and engineers were trained in Toshiba’s and Siemens’ 2 and 3 µm production line and in Lucent’s 0.9 µm production line.

Others

One of the major IC manufacturing projects in China recently is the Mitsubishi-Stone Semiconductor Co. Ltd. (MSSC), a joint venture of Japan‘s Mitsubishi Electric Corporation and Mitsui Co., Ltd., and the Beijing Stone Group Company. The company was founded in 1996 with registered capital of $35 million. Total investment is $2 billion, of which the Japanese side holds 70 percent and the Chinese side 30 percent of the shares. The primary products are MCU, ASIC, and SRAM with the technology goals of 0.28~0.35µm and 8~10-inch wafers. The project is expected to produce 210 million ICs. The first phase of this project (back-end packaging and test) went into production in October 1998. The second phase (semiconductor design center) is in progress with a projected investment of $110 million. [Stone Group, 2000].

Two new fabs are planned for construction in the special economic development zone of Shenzhen, near Hong Kong. The government is negotiating with STMicroelectronics to jointly build a fab in the special economic zone. The first fab will produce 30,000 6-inch wafers per month using a processing technology of 0.5 to 0.35 µm. The second fab will scale down to 0.2 µm, producing 25,000 wafers per month. The planned fabs will serve as foundries to supply devices for the country’s telecommunications and consumer-electronics industries [Cataldo 1999]. The first phase of the project – Shenzhen Sai Yi Fa Microelectronics Co. Ltd. (back-end packaging and IC design canter) -- was completed and put into production in 1997. The joint venture was co-funded by Shenzhen Saigew High-Tech Investment Stock Holding Co. Ltd. and STMicroelectronics with a total investment of $115 million.

ROLE OF FOREIGN COMPANIES

In order to narrow the technological gap between China and other industrial nations, the Chinese Government is inviting foreign companies to set up manufacturing in China. They have set up various technologies parks with major tax incentives to entice companies. However, China generally seeks to maintain control over the direction and decision-making of companies operating in China, and this can be a problem for foreign companies doing business there. Other problems for foreign companies include lack of adequate protection for intellectual property and inconsistencies between different branches of the Chinese Government. For U.S. companies there is the additional problem of working within U.S. laws that govern export of “dual use” products and equipment that could be turned to military purposes considered detrimental to U.S. security interests.

Current U.S. trade policy toward China is to deny export and technology licenses for fabrication equipment that can produce ICs using below 0.35 µm process technology. The U.S. position is that export controls are needed to prevent the Chinese from making high-tech ICs for missile and nuclear weapon technologies. As a result, for China to become a significant player in the global IC market, it must extend the scope of international cooperation and speed up the current progress in indigenous technology development.

For a decade now, companies from the United States, Europe, and Asia have been building and equipping factories in China, training engineers and operators, and co-managing manufacturing operations, despite less than ideal conditions. Companies active in China's semiconductor industry, drawn by the low-wage labor force as well as by the huge potential Chinese market, include AT&T, IBM, Intel, Fujitsu, Motorola, Mitsubishi, National Semiconductor, NEC, Philips, Rockwell, Siemens, Texas Instruments, and Toshiba — all intensely competitive with one another. In addition, China is separately purchasing processing equipment from the United States, Japan, and Europe to help expand production capacity, particularly in 0.8 to 1.0 µm and 6 inch technology, and there are opportunities for equipment suppliers offering 0.5 µm (and smaller) and 8-inch technology. The Motorola, Shougang-NEC, and Hua Hong-NEC plants already have given China some advanced chip making capabilities.

The Chinese Government, through the Ministry of Information Industries (MII), has listed the production of ICs as a priority development item. The Chinese Government is eager to seek technology transfer and investment from foreign countries – by giving investors preferential treatment and an opportunity to gain the inside track in China's huge market.

In 1998, the Chinese Government notified the U.S. Department of Commerce that it was ready to exempt tariffs on imported capital semiconductor equipment capable of making 0.25 µm or lower line technologies [Robertson 1998b]. In 1999, an agreement was reached by the Chinese Government and the U.S. Government on China's entry to the World Trade Organization (WTO). Under the terms of the agreement, China agrees to eliminate all tariffs on semiconductors, computers, and telecom products by 2005 and to adhere to global standards safeguarding intellectual property. China will also remove its requirement that the country's foreign chip fabs and assembly plants export most of their output [Robertson 1999]. The pact will open the way to greater direct investment in China and relax U.S export controls.

Compared with the United States, both Japan and Europe have greater freedom to approve the export of advanced semiconductor equipment, since a global system of controls called CoCom (Coordinating Committee on Export Controls) was eliminated several years ago [Robertson 2000]. NEC is the largest Japanese company to invest in the Chinese microelectronics industry. A new fab is in the plan as a joint venture between Mitsubishi (Japan) and Stone. Shenzhen Saigew Group is negotiating with STMicroelectronics (a joint venture between Italy and France) for construction of two IC foundries in Shenzhen.

Taiwan does not appear to have invested in IC fabrication in China. For Project 909, the Chinese Government initially planned to set up a foundry with TSMC [Lammers 1997], but it was unsuccessful. The primary investments of Taiwan companies are in printed circuit board production and component assembly, which require much less capital expenditure. The largest Taiwan investment in China so far has been the Acer Inc. computer main board plant; with a total investment of less than $96 million, since the government of Taiwan only allows Acer to invest under $30 million per year in any given project [Carroll 2000].

IC INDUSTRY ASSESSMENT

In 2000, the Chinese IC industry can be characterized by the following features:

- Inadequate capacity and low productivity. China can satisfy only 20 percent of its domestic needs.
- Strong competition. China must compete against Western and Asia-Pacific companies equipped with much better technologies and financial resources.
- Poor infrastructure. China's IC infrastructure is immature. Lack of peripheral industries (e.g., equipment manufacturing, assembly, and testing) is a major concern for future growth.
- Inadequate research and development. Most of the advanced technologies are acquired from foreign countries.

- Rapidly growing and sophisticated design capabilities. This may potentially negate the other problems.
- Strong government support.
- The major emphases in the development of China's semiconductor industry in the coming century will be seen in the following areas:
- IC design capabilities;
- Wafer preparation and chip manufacturing, including polysilicon, crystal silicon preparation and process, doping process, pattern micro fabrication, dielectric thin-film technology, metal thin-film technology, and clean room techniques;
- IC assembly, testing, and reliability.

The 64 Mbit DRAMs made recently by the Shougang NEC Electronics Co., Ltd. and Shanghai Hua Hong Group Co. Ltd., both of which are Sino-Japanese joint ventures, indicate that China's manufacturing technology of large ICs is on track to catch up to the level of industrialized nations. But China has yet to achieve mass production of ICs by using 0.35 μm process technology. Other areas targeted for major development efforts include 1Mb SRAM, 4 Mb ROM, IC cards containing EPROM, flash memory, 200k CMOS gate array, 300k CMOS standard cell, 50k BiCMOS gate array, and high-performance DSP. If the current pace of technological progress in China continues without disruption, it is expected that by the year 2005, 0.35 μm process technology will be implemented in mass production of ICs. By the year 2010, China may also expect to reach the technological level of 1M gate array, 250 K BiCMOS gate array, 4~16 Mb SRAM, 4~16 Mb flash memory, and 128 Mb DRAM.

China's party, governmental and industrial bureaucracies have held back the country's advance as an electronics consumer and manufacturer for decades. However the giant is awakening, and China will reshape the landscape of the global electronics industry as it assumes a role on the world stage. The power of a market consisting of 1.2 billion people cannot be ignored.

ACKNOWLEDGEMENTS

Research for this paper was supported through the TTEC program managed by Loyola College in Maryland. Some information of this paper was taken from the book *The Chinese Electronics Industry*, authored by M. Pecht et al. in 1999.

REFERENCES

Advanced Semiconductor Manufacturing Corporation of Shanghai (ASMC). *Company Website*. [On-line], Available: http://www.asmcs.com/

Asia Pulse. "China to be world's largest telephone IC card market." *Asia Pulse*. May 31, 1999.

Asia Pulse. "China's IC market valued at 46.2 BLN yuan in 2000." *Asia Pulse*. March 17, 2000a.

Asia Pulse. "China's Hua Jing to supply Lucent with telecom IC chips." *Asia Pulse*. April 3, 2000b.

Belling Microelectronics Manufacturing Co. Ltd. *Company Website*. October 1996. [On-line], Available: http://www.belling.com.cn/

Carroll, Mark. "Acer ramps up giant fab in China." *EE Times*. February 7, 2000. [On-line], Available: http://www.techweb.com/se/directlink.cgi?EET20000207S0039

Cataldo, Anthony, and Leopold, George. "China feels squeezed by U.S. export policy." *EE Times*, March 22, 1999. [On-line], Available: http://www.techweb.com/wire/story/TWB19990322S0003

China Electronics Industry yearbook 1999. Electronics Industry Publisher, Beijing, China (in Chinese).

China Hua Jing Electronics Group Corporation. *Company Website*. [On-line], Available: http://www.huajing.com.cn/

China Hua Jing Electronics Group Corporation. *Daily Report*. March 13, 2000. [On-line], Available: http://www.huajing.com.cn/xxjj/03-13.txt (in Chinese)

China Hua Jing Electronics Group Corporation. *Daily Report*. March 22, 2000. [On-line], Available: http://www.huajing.com.cn/xxjj/03-22.txt (in Chinese)

China Hua Jing Electronics Group Corporation. *Daily Report*. April 4, 2000. [On-line], Available: http://www.huajing.com.cn/xxjj/04-04.txt (in Chinese)

China Economic Information Technology (IT) Market Report. "Circuit designing firm to spur electronic industry." December 29, 1998. [On-line], Available: http://www.chinaeco.com/ecit/c5220l99.htm

China Economic Information Network (CEInet). [On-line], Available: http://www.chinaeco.com/

China Vista. "Lucent to complete contract." March 5, 1998. [On-line], Available: http://www.chinavista.com/business/news/archive/mar98/mar05-02.html

CMSC-Hua Jing Co. Ltd. *Company Website*. [On-line], Available: http://www.csmc.com.cn/

Howell, Thomas R., Nuechterlein, Jeffrey, D., and Hester, Susan B. *Semiconductors in China: Defining American Interests*, Semiconductor Industry Association, Dewey Ballantine, 1995.

IEEE. "Chip making in China: Snapshots of China." *IEEE Spectrum*, December 1995.

Intel Corporation. "Intel commitment to China." *Press Releases*, May 1998. [On-line], Available: http://www.intel.se/apac/eng/andygrove/pr0505.htm

Johnson, Grant. "Is China's semiconductor market worth the risk for multinationals? Definitely!" Electronic News, March 29, 1999a. [On-line], Available: http://www.instat.com/insights/semi/1999/china42999.htm

Johnson, Grant. "China promotes chips as pillar of growth." *Information Alert*. April 26, 1999b. [On-line], Available: http://www.instat.com/infoalert/alrt199917.htm

Keliher, Macabe. "TSMC moving quickly to 0.13-micron process technology." *Electronic Buyers' News*. March 30, 2000. [On-line], Available: http://www.ebnews.com/printableArticle?doc_id=OEG20000330S0005

Koo, George P. " China seeks world-class semiconductor industry." *Channel Magazine*. November 1997. [On-line], Available: http://www.semi.org/Channel/1998/nov/features/china.html

Lammers, David. "Japan gaining inside track to China's chip market." *EE Times - Headline News (CMP Media, Inc.)*, 1997. [On-line], Available: http://pubsys.cmp.com/eet/news/97/956news/japan.html

Leopold, George. "Microchip plans three more design centers in China." *EE Times*, march 31, 2000. [On-line], Available: http://www.semibiznews.com/story/OEG20000331S0029

Liu, Sunray. "A design industry begins to grow up in China." *EE Times*, October 19, 1998.

Liu, Sunray. "In rising market, 150 million smart cards set for 1999 issue - China's IC-card industry draws global players." *EE Times*, August 2, 1999a. [On-line], Available: http://www.techweb.com/se/directlink.cgi?EET19990802S0030

Liu, Sunray. "Motorola to open design center in China." *EE Times*. October 13, 1999b. [On-line], Available: http://www.semibiznews.com/story/OEG19991013S0031

Liu, Sunray. "Chinese chip designers take a market-driven tack." November 15, 1999c. [On-line], Available: http://www.techweb.com/se/directlink.cgi

Liu, Sunray. "Indigenous design industry gains ground in China." *EE Times*. November 11, 1999d. [on-line], Available: http://www.eet.com/story/OEG19991111S0019

Liu, Sunray. "China to fund IC design complex in Shanghai." *EE Times*. March 8, 2000a. [On-line], Available: http://www.semibiznews.com/printableArticles?doc_id=OEG20000308S0042

Liu, Sunray. "Local production plans cement commitment to potentially vast market - Motorola earmarks $2B for MCU fab in China." *EE Times*, February 7, 2000b. [On-line], Available: http://www.techweb.com/directlink.cgi?EET20000207S0038

NEC. "NEC signs contract for China's largest semiconductor project." *News Release*. May 1997. [On-line], Available: http://www.nec.co.jp/english/today/newsrel/9705/2801.html

Pecht, Michael, Lee, Chung-Shing, Zong, Xiang-Fu, Jiang, Jun-Lu, and Wang, Yong-Wen, *The Chinese Electronics Industry*, CRC Press LLC, Boca Raton, FL, 1999.

Robertson, Jack. "Motorola plans "superfab" site in China." *Semiconductor Business News*, May 5, 1998a.

Robertson, Jack. "China policy dominates chip meeting." *Electronic Buyers' News*. May 4, 1998b. [On-line], Available: http://www.techweb.com/news/story/TWB19980504S0025

Robertson, Jack. "China agrees to eliminate chip tariffs." *Electronic Buyers' News*. November 22, 1999. [On-line], Available: http://www.techweb.com/se/directlink.cgi?EBN19991122S0001

Robertson, Jack. "NEC's Shanghai fab set to crank out 128-Mbit DRAMs." *Semiconductor Business News*, March 29, 2000. [On-line], Available: http://www.semibiznews.com/story/OEG20000329S0026

Schumann, Elizabeth. "Market focus: China. A feature of SEMI's equipment and materials market statistics program." *Channel magazine*, February 1997. [On-line], Available: http://www.semi.org/Channel/1997/feb/market.html

Simon, Denis Fred. "From cold to hot -China struggle to protect and develop a world-class electronics industry." *The China Business Review*, Vol. 23, No. 6, November-December 1996, pp. 8-16.

Shanghai Hua Hong Group Co. Ltd. *Company Website*. [On-line], Available: http://www.huahong.com.cn/

Shenzhen Saigew High-Tech Investment Stock-Holding Co. Ltd. *Company Website*. [On-line], Available: http://www.shic.com/

Shougang News. *Capital Iron and Steel Co. Website*. [On-line], Available: http://www.shougang.com.cn/ (in Chinese)

Stone Group Corporation. *Company Website*. [On-line], Available: http://www.stone-group.com/ (in Chinese).

The China IC Design Center (CIDC). *Company Website*. May 2000. [On-line], Available: http://www.cidc-cn.com.cn/index.html

The National Engineering Center for ASIC Design (NECFAD). *Company Website*. May 2000. [On-line], Available: http://www.cnerc.gov.cn/

Tsuda, Kenji. " China pushes sub micron chip fabs." *Nikkei Electronics Asia*, Vol. 6, No. 2, February 1997. [On-line], Available: http://www.nikkeibp.com/nea/feb97/febchina.html

Weng, Shuo Song. "A survey of the Chinese IC industry." *Solid State Technology China*, November 1996, pp 14-17. (in Chinese).