Advanced Integrated Circuit Manufacturing Technology Process Industry Development

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Abstract. Integrated circuits are circuits with specific functions that are integrated together by semiconductor processes and are a new type of semiconductor device developed in the late 1950s through the 1960s. Integrated circuits are the foundation of information development and the benchmark for high quality development of national economy. This paper introduces the concept of integrated circuits as well as the integrated circuit process, and the application areas of integrated circuits, which account for an expanding and growing share of information, communication, consumer electronics, automotive electronics, medical electronics and other consumer areas. It discusses China's future IC process development path by combining the IC production process and design process, industrial development, design process and preparation limitations, and proposes relevant suggestions and strategies by speculating on the future development of the process.

Keywords: Industrial development; integrated circuit; manufacturing industry; design.

1. Introduction

Integrated Circuit is a certain number of commonly used electronic components, such as resistors, capacitors, transistors, etc., as well as the wires between these components, through the semiconductor process integrated together with a specific function and in the late 1950s developed a new type of semiconductor device. It is after oxidation, photolithography, diffusion, epitaxial, evaporation of aluminum and other manufacturing processes, the composition of the circuit with a certain function of the components required and the wires between them are integrated in a small piece of silicon, and then welded and encapsulated in a shell of electronic devices. Encapsulation shell has a round shell, flat or double in-line type and other forms. One of the integrated circuit technologies including chip manufacturing design technology, embodied in the equipment, process, packaging and testing, mass production and innovative design capabilities [1]. The degree of integration and product performance of integrated circuits doubles every 18 months. The next 20 years or so, integrated circuit technology and its products will still follow this law of development. 20 centuries in the mid-1980s China's integrated circuits processing level of 5 micron, and subsequently, experienced the development of 3, 1, 0.8, 0.5, 0.35 micron [2]. currently reached the level of 14 nanometers, while the current highest international level of 7 nanometers. In the design and fabrication profile process flow, the future development plan is hypothesized from the current application areas and preparation limitations in China, and certain improvement measures are proposed.

The main purpose of this article is to introduce integrated circuits (IC) and the understanding of advanced IC processes, and on top of that to discuss the main problems of IC fabrication processes and how to improve them. First of all, it briefly introduces the rapid development of integrated circuits as a new type of device developed in recent times, as well as the improvement of the process program, the development of the industrial chain in China and the general plan for the future.

2. Integrated Circuit Manufacturing Industry

2.1. lassification of Species

Integrated circuits according to different roles can have a variety of different classifications, which can be divided into analog integrated circuits, digital integrated circuits and digital-analog hybrid integrated circuits according to the functional structure. Analog integrated circuits, also known as linear circuits, used to generate, amplify and process a variety of analog signals (amplitude of signals varying with time), its input signal output signal proportionality. Digital integrated circuits are used for digital signals (time and amplitude of the discrete value of the signal) processing.

In addition to this, according to the different production processes can be divided into two categories of semiconductor and film integrated circuits; according to the different types of conductivity can be divided into unipolar and bipolar circuits, on the basis of which both are digital integrated circuits; in the field of application can be divided into standard general-purpose integrated circuits and specialized integrated circuits. Finally, it can also be categorized according to the shape of the round, flat and double-row in-line type and so on.

2.2. Industrial Development

Since the 1970s, the world IC market has shown a wave-like growth trend, with an average annual growth rate of about 15%. As the IC industry becomes more mature, the competition is more rational, "Eleventh Five-Year Plan" period of the world IC market will enter a stable stage of development, fluctuations tend to slow down, the average annual growth rate is expected to be about 14%, in 2010 to reach about 300 billion U.S. dollars. From the domestic market, the "Eleventh Five-Year" period of the domestic electronic information machine industry, especially notebook computers, mobile communication terminals and other products will continue to maintain rapid development, it is expected that in 2006, 2007, China's IC market size growth rate slightly faster than the global growth rate of about 20%. "Eleventh Five-Year" in the late stages, with the development of the domestic electronic information machine market stabilized, China's electronic information products manufacturing scale of the growth rate will fall back to less than 20%, the integrated circuit market growth will also slow down, the growth rate will be slightly higher than the world average, an average of about 15% per year. According to this estimate, by 2010 China's integrated circuit market size will exceed 830 billion yuan. In the import and export trade, taking into account the "Eleventh Five-Year Plan" period of China's integrated circuit industry technology and industrialization level is difficult to meet the demand for the situation cannot be fundamentally reversed, the trade deficit will continue to show Fig. 1 for the development of 2015-2020 [3].

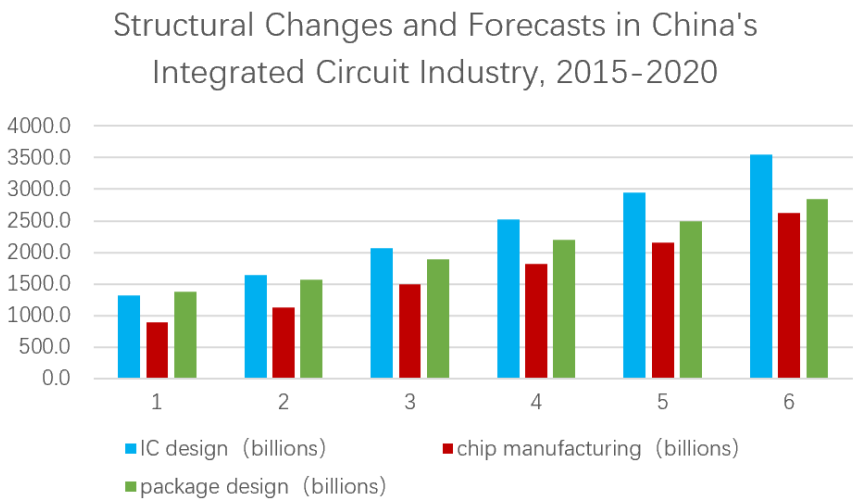


Fig. 1 Structural Changes and Forecasts of China's Integrated Circuit Industry, 2015-2020. (Photo/Picture credit: Original)

3. Integrated Circuit Design and Manufacturing

3.1. IC Design Flow Industrial Development

Integrated circuit design process first to the division of hardware and software design, the basic process is divided into two parts: circuit chip hardware design and software co-design steps. These two steps in the operation of the main process: circuit design, pre-simulation, layout design, post-simulation, follow-up processing and a series of steps.

3.2. IC Design Flow

Integrated circuit fabrication is the performance of a series of complex chemical or physical operations on silicon wafers. These operations are summarized in four basic categories: thin-film fabrication, imprinting, etching, and doping. Integration was conceived in the late 1950s and early 1960s and was realized using silicon planar technology and thin and thick film technology. Electronic integration technology is categorized by process method into monolithic integrated circuits based on silicon planar process, thin-film integrated circuits based on thin-film technology, and thick-film integrated circuits based on screen-printing technology [4].

3.2.1 Film production

Thin-film integrated circuits are made using thin-film processes on sapphire, quartz glass, ceramics, and copper-clad laminate substrates to produce circuit elements, devices, and their wiring, and finally encapsulated. IC thin film deposition process can be divided into three categories, for the physical vapor deposition (PVD), chemical vapor deposition (CVD) and epitaxy. Thin-film hybrid integrated circuits need to use a variety of substrates, generally used the most is a glass substrate, followed by microcrystalline glass and was glazed ceramic substrate, and sometimes also with sapphire and monocrystalline silicon substrate. The process includes evaporation, sputtering, chemical vapor deposition and so on. Characterized by more precise control of resistance and capacitance values [5].

Photolithography is the process of leveling the surface of a silicon wafer and then transferring the graphics on a mask plate to the photoresist. It is the process of temporarily "copying" a device or circuit structure onto a silicon wafer. Photolithography accounts for almost one-third of the overall wafer processing cost. Photolithography accounts for 40% to 50% of the flow time. It is the most important module in the IC process and is the key process technology in integrated circuits, which was first conceived as a photolithographic plate in printing technology. Photolithography was first applied in 1958 and enabled the fabrication of planar transistors [6].

3.2.2 Etch

Etching technology is in the semiconductor process, in accordance with the mask pattern or design requirements of the semiconductor substrate surface or surface coverage of thin film selective etching or stripping technology. Etching technology is not only the basic manufacturing process of semiconductor devices and integrated circuits, but also applied to thin-film circuits, printed circuits and other microfabrication. Etching can also be divided into wet etching and dry etching [7].

3.2.3 Jumbled

Doping refers to a certain number of certain impurities, such as III valence element boron or V valence element phosphorus, arsenic, etc. doped into the semiconductor substrate, in order to change the electrical properties, and to make the doped impurity number, distribution form and depth, etc. to meet the requirements. Doping process is mainly divided into thermal diffusion and ion implantation. Thermal diffusion refers to when the ambient temperature increases, the substrate material atoms in the equilibrium lattice: point near the vibration, some of them will get enough energy and leave the equilibrium lattice point, to become in the gap-filling state of the atoms, at the same time in the original lattice on the resulting vacancies. Vacancy diffusion occurs when neighboring impurity atoms or matrix atoms migrate into the vacancies. Ion injection refers to the process of accelerating

an ion beam to a certain energy and then injecting it into the surface layer of a solid material in order to change the physical properties of the surface layer of the material.

4. Application Areas and Preparation Limitations

4.1. IC Application Areas

Integrated circuits (ICs) are the main foundation and power source of today's rapidly developing information technology industry, which has highly penetrated into every area of the country's economic development and social infrastructure. At present, the proportion of integrated circuits in information, communication, consumer electronics, automotive electronics, medical electronics and other consumer fields is expanding and maintaining growth.

4.2. IC Preparation Limitations

China's IC product manufacturing aspects of a wide range of rich, but the overall manufacturing capacity is weak, for example, China's product self-sufficiency rate is low, manufacturing chips accounted for only 2.1% of the world, including China's market self-sufficiency rate of only 5.9%. 2020 China's imports of chips to nearly 380 billion U.S. dollars (equivalent to about 2.4 trillion people's dollars), accounting for about 18% of China's total imports; In addition, the industry's key technologies are limited, resulting in a certain blow to the path of industrial development, high-end chip supply gap is large, the chip shortage of market problems have gradually spread from the automotive industry to the cell phone, security and other market areas; wafer fabs, photolithography, process manufacturing and other upstream and downstream industries. China's move towards the road of independent innovation, will prompt China to invest more power to master the core technology, industry and the gap between the international advanced level will continue to narrow, localization is expected to accelerate the replacement process. Secondly, China's IC field of high-end talent scarcity, which is the most lack of a high level of innovation and vigor and international competition of practical talents, which is also a key reason for the development of the industry constraints. According to the statistics of China's Ministry of Industry and Information Technology data, the scale of demand for talents in China's IC industry in 2021 is about 722,000 people, but there is a talent gap of 261,000 people, so accelerate the cultivation and introduction of people has become an urgent problem. Talent cultivation requires a perfect education system and long-term investment, investment can not be solved in a short period of time to solve the shortage of high-quality talent short board. 2020 December, the State Council Academic Degrees Committee and the Ministry of Education jointly issued a notice, will be set up as a first-class discipline IC and through the integration of industry and education model to explore, multi-party collaboration and coordination to cultivate the country's top talent, to make up for the shortage of personnel, will gradually alleviate the industrial The pressure of "talent shortage" [8, 9].

5. Future Directions

5.1. Directions

China's integrated circuits have formed a number of industrial clusters. In terms of spatial layout, there are mainly four industrial clusters and a ladder-like development pattern. They are the Yangtze River Delta centered on Shanghai, which is the core development area of China's IC industry, with the largest share of 47.7% of the national share of the manufacturing and testing industry (Fig. 2); the Beijing-Tianjin Bohai Rim area centered on Beijing, which is the core of the development of the domestic IC design industry and manufacturing industry the Pan-Pearl River Delta centered on Shenzhen, which is the core area for the development of China's IC design industry, with a share of nearly 20% of the industrial sales; the Pan-Pearl River Delta centered on Sichuan, Shaanxi, Hubei, Hunan, Chongqing, Anhui, Gansu and other industrial clusters in China. 20%; to Sichuan, Shaanxi,

Hubei, Hunan, Chongqing, Anhui, Gansu and other provinces as the representative of the central and western regions, business management is in the second echelon of industrial development. With the deepening of China's development of the IC industry, the development of the industry chain will be gradually improved, and the advantages of industry clusters will be further emphasized [10].

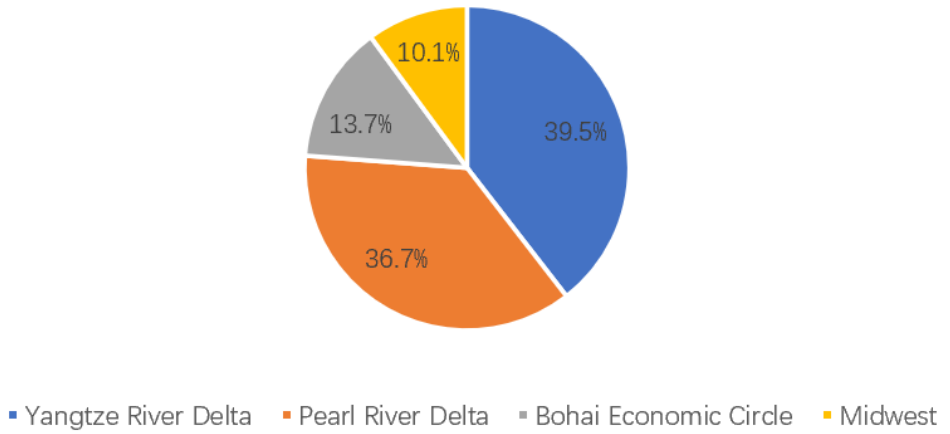


Fig. 2 Spatial distribution of integrated circuits in China in 2020. (Photo/Picture credit: Original)

5.2. Recommendations and Measures

Accelerate the development of industry modern system IC industry as a global collaborative industry, the development of the industrial chain involves many links, supporting high degree of relevance, upstream and downstream collaboration. Strengthen the cultivation of talents in short supply from the structure of IC practitioners, China's internationalization of the IC industry, high-level, complex talent is relatively lacking, should adhere to the training and introduction of talent and the introduction of foreign industry, and vigorously introduce outstanding talents and teams, as soon as possible to form a multi-level internationalization of high-level, complex talent echelon. Deepen the industry open cooperation, integrated circuit is a highly globalized industry, industrial globalization division of labor cooperation mode is more mature [11]. China's IC industry has a weak foundation, and there is still a large gap with the international advanced level, the globalization of IC division of labor situation is facing a huge challenge to develop their own at the same time, adhere to the opening up to the outside world, and continue to optimize the environment for the development of the industry, to attract foreign capital, technology and talent, to undertake the transfer of international high-end industries. Take the initiative to grasp the new opportunities for development, strengthen international exchanges and cooperation, participate in the division of labor and coordination of the industrial chain, and actively and effectively integrate into the global industrial chain, supply chain and value chain.

6. Conclusion

China is currently in a critical period of development of integrated circuit (IC) manufacturing. This paper starts from the concept of IC and the process of IC production, introduces what is IC and the process of IC production, and expounds the limitations and bottlenecks encountered by China's IC production industry through the level of process and China's introduction of chips, and then finally derives suggestions for the future development of the industry in this way. For China's late start and recent years of international restrictions on the development of China's integrated circuits, the future should strengthen the opportunities for international exchanges and cooperation at home and abroad, as well as the construction of the domestic industry talent echelon, so as to accelerate the development of China's industry. For the current understanding of integrated circuits and the development of China's integrated circuit process status, planning for the future development of the industry's recommendations, this paper has a certain reference to adopt the significance.

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