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Overview of the development of chip manufacturing technology

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Abstract. With the rapid progress of modern science and technology, the manufacturing process of chips, which serves as the core of microelectronics technology, plays a crucial role in both producing and improving electronic products. With the advancement of science and technology and the continuous growth of market demand, the research and development of the chip manufacturing process has become more and more critical. This paper explores the historical development, essential technologies, and prospects related to chip manufacturing. It provides a comprehensive understanding of this field through six sections including an introduction, overview of the process, application areas, key technologies, future trends, and concluding remarks. This study offers valuable guidance and reference for related industries and research fields. It is found that the chip process has an important position and broad application prospects in the field of modern science and technology. In the future, chip manufacturing processes will move towards smaller feature sizes. Future chip manufacturing processes will pay more attention to process optimization, and improve the process flow to reduce loss and waste, in order to improve the efficiency and reliability of chip production.

Keywords: Chip manufacturing process, Lithography, Mechatronics

1. Introduction

With the rapid development of modern science and technology, chip manufacturing process, as the core of microelectronics technology, plays an important role in the manufacture and performance improvement of electronic products. Chip fabrication process refers to the process of manufacturing microelectronic components and circuits on silicon-based materials through a series of process steps. With the advancement of science and technology and the continuous growth of market demand, the research and development of chip manufacturing process has become more and more critical.

The purpose of this paper is to conduct an in-depth study on the chip manufacturing process, and discuss its development history, key technologies and future trends. This paper is divided into six parts. The first is the introduction, which includes background information, research questions and objectives, and an overview of the paper structure. What follows is an overview of the chip process process, covering its definition, development history, and current application areas. The third part discusses the application cases of the chip manufacturing process, emphasizes its importance, and lists the current industrial application cases. In the fourth part, the key technologies of chip manufacturing process are introduced in detail, including lithography technology, ion implantation, chemical vapor deposition, mechatronics application in chip manufacturing process, and other related technologies. The fifth part

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discusses the future trends of chip manufacturing processes, including advanced processes and materials, process optimization and efficiency improvement, and environmental considerations. The last part summarizes the findings of the study, discusses the limitations of the study, and proposes suggestions for future research. Through a comprehensive understanding of the chip manufacturing process, it provides guidance and reference for related industries and research fields.

2. Overview of chip manufacturing process

2.1. Definition of chip manufacturing process

Chip manufacturing process refers to a series of process steps and technical methods used in the manufacturing process of integrated circuits (chips). It covers all aspects from the chip design to the final product, including material selection, mask production, lithography, etching, deposition, ion implantation, heat treatment, film preparation, chemical-mechanical grinding, and cleaning. Precise and optimized chip manufacturing processes directly determine chip performance, reliability and cost effectiveness. In this field, the control and optimization of process parameters is very important, and the precise control of chip performance and electrical characteristics can be achieved by adjusting process parameters. In addition, factors such as production cost, scalability and product qualification rate are also essential to ensure that the chips produced are of high quality and competitive in the market. With the continuous development of scientific and technological advances, traditional lithography processes have evolved into advanced technologies such as nanoscale machining and three-dimensional integration, which play an important role in improving chip performance levels, achieving a higher degree of integration, and reducing power consumption. Therefore, the continuous improvement and innovation of the chip process is of great significance to promote its application prospects and has been an extremely important and active research area in the integrated circuit industry.

2.2. Development history

The history of the development of the chip process process can be traced back to the late 1950s and early 1960s. In 1958, the American physicist Jack Kilby first proposed the concept of integrated circuits, laying the foundation of the chip manufacturing process. In the early 1960s, the chip manufacturing process used discrete component manufacturing processes, such as microcrystalline tubes and thin film transistors, and mainly relied on manual completion, resulting in low production efficiency. However, in the late 1960s, with the advancement of technology, the first generation of large-scale integrated circuits (LSI) was developed and multiple transistors were integrated on the same silicon chip, which significantly improved the performance and integration of integrated circuits. Subsequently, in the mid-1970s and early 1980s, with increasing integration, metal-oxide-semiconductor field-effect transistors (MOSFETs) gradually replaced other structures as the primary transistor, playing a key role in reliability and performance[1]. The introduction of lithography, beginning in 1980, greatly improved the precision and resolution of the chip manufacturing process, making it more feasible to accurately define individual components and wires on silicon wafers. The rise of the Internet and the wide application of personal computers in the 1990s led to a sharp increase in the demand for high-performance, low-power integrated circuits. In order to meet these needs, new process technologies have emerged, such as sub-micron processes, multi-layer metal interconnects, and so on. Since 2000, with the popularity of mobile communication and smartphones, chip manufacturing process has entered the nanoscale period and sub-nanoscale technologies such as FinFET(fin field effect)structures have been introduced to further improve chip performance and power efficiency[2]. Today's chip manufacturing process continues to move deeper into the nanoscale, and involves more innovative technologies and materials such as 3D integrated circuits, gallium nitride, silicon-based photonics and other fields that continue to evolve to meet the requirements of emerging applications such as artificial intelligence, the Internet of Things and 5G.

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3. Current application field

Chip process technology is widely used in many fields such as computers, telecommunications, consumer electronics and medical equipment. With the rapid development of emerging technologies such as artificial intelligence and the Internet of Things, the demand for chip process processes is also increasing. In the production of electronic devices such as high-performance processors, memory and sensors, the chip process plays a decisive role. It refers to the process of integrating electronic components such as transistors, resistors, capacitors into the chip, which has a crucial position in the modern electronics industry and involves the manufacturing process of almost all electronic devices.

In the field of communication, the chip manufacturing process is widely used in mobile communication equipment, network equipment and satellite communication. For example, Huawei uses a variety of chip manufacturing processes in the field of communications, including mobile communication base station chips, 5G communication chips and optical network transmission chips.

In the field of smart terminals, the technology is widely used in smartphones and consumer electronics. Huawei's smartphones, for example, use high-performance processor chips and are equipped with other types of chips related to wireless communications, image processing and sensing functions

Huawei has also widely used the technology in cloud computing, automotive industry and other fields [3]. The impact of chip manufacturing on our lives is immeasurable.

4. Key technologies of chip manufacturing process

Lithography is one of the most critical technologies in chip manufacturing process. It uses a lithography machine to project the pattern formed by the mask onto the photosensitive material layer by light, so as to achieve the formation of the desired pattern. Lithography technology has a direct and significant impact on the fabrication accuracy and functional performance of chips [4].

Ion implantation is a key technology that changes the electrical properties and impurity concentrations of chip materials by introducing ion beams. The method can be used to prepare pn structures, improve crystal defects, and regulate conductive and insulating regions [5].

Chemical vapor deposition (CVD) is a key technology that produces a solid film by gaseous chemical reaction on the surface of a chip. The method is suitable for the deposition of a variety of materials, including metals, insulators and semiconductors, and can realize the manufacture of electrodes, insulation layers and electronic components [6].

Mechatronics technology combines mechanical and electronic technology, which is widely used in the field of automation and intelligence, and is widely used in the chip manufacturing process. This technology significantly improves machining accuracy and stability while reducing the need for human intervention and production costs [7].

In addition to the above key technologies, there are many other related technologies that are applied in the chip manufacturing process. For example, using chemical mechanical polishing (CMP) and other smoothing methods to improve the flatness of the chip surface; At the same time, the required thickness of the film material was obtained by the film precipitation method. In addition, methods such as the removal of unwanted substances by rot erosion are also adopted [8].

5. The future trend of chip manufacturing process

5.1. Advanced technology and materials

With the continuous progress of science and technology, the chip manufacturing process is also continuing to evolve. Advanced technology usually refers to the reduction of process nodes, that is, the minimum feature size used in the manufacture of chips. In the past few decades, the chip manufacturing process has developed from the micron level to the nanometer level, and has entered the stage below 10 nm. In the future, chip manufacturing processes will move towards smaller feature sizes, including nodes of 7 nm, 5 nm or even smaller [9]. This will result in higher integration, lower power consumption and better performance. In addition to node reduction, the chip manufacturing process also relies on the

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development of advanced materials. These include advanced materials such as semiconductor materials, dielectric materials and metal materials. As nodes shrink, traditional materials may be subject to some physical and electrical limitations, so new types of alternative or improved performance materials need to be developed. For example, semiconductor materials such as Gallium Arsenide and Silicon Carbide have advantages in high frequency and high temperature applications; High dielectric constant materials can be used to reduce the gate voltage to reduce power consumption. In the future, advanced materials research will continue to drive the development of chip manufacturing processes.

5.2. Process optimization and efficiency improvement

Future chip manufacturing processes will pay more attention to process optimization, and improve the process flow to reduce loss and waste, in order to improve the efficiency and reliability of chip production. In order to achieve this goal, the process will continue to develop towards higher integration and smaller sizes, such as 7nm, 5nm, 3nm and other process nodes. At the same time, with the introduction of new materials and new processes, such as three-dimensional stacking technology and micro-nano optical technology, the performance of the chip will also be further improved. In addition, process technology will focus more on innovation in improving the energy efficiency and reliability of chips, with more efficient energy management and heat dissipation technologies, as well as more reliable hardware design and manufacturing processes.

5.3. Environmental considerations

With the increasing global awareness of environmental protection, the trend of future chip manufacturing processes will pay more attention to environmental protection and sustainable development. Through measures such as greening, energy efficiency improvement, circular economy and environmental management, the win-win situation between chip manufacturing and environmental protection will eventually be realized.

6. Conclusion

Through the introduction of the chip process and the analysis of key technologies, it is clear that the chip process has an important position and broad application prospects in the field of modern science and technology. This study mainly focused on the overview of the chip manufacturing process and key technologies, although it could not delve into the specific manufacturing process and its details. In order to further promote the development of chip manufacturing processes, we encourage future research to explore emerging technologies and methods, and strive to improve process efficiency and environmental friendliness.

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