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Important Scientific and Technical Issues in Computer Manufacturing

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Abstract

An overview of the computer manufacturing technology is given. Its important role in the development of the national economy is discussed, and its characteristic, current status and development trend are analyzed. Then, two science technologies rising from hard disk manufacturing and IC chip packaging,i.e., interface behavior and control, motion control and accuracy synthesis, are introduced in detail, and some relevant open scientific problems are presented for further research.

Keywords

Hard disk; IC chip computer Manufacturing technology.

1. INTRODUCTION

Computer manufacturing science and technology does not refer to the computer-aided manufacturing (CAM) concept, but refers to the manufacturing science and technology in the information industry related to the manufacturing of computers, such as the post-encapsulation manufacturing of computer disks, heads, and chips. Prof. Wright of UC Berkeley in 2001 "21st Century Manufacturing", Point out Semiconductor Manufacturing (Semiconductor manufacturing, IC Packaging) and Computer Manufacturing (Computer manufacturing, PCB Board Assembly and Hard Drive Manufacturing) will represent the forefront of the 21st century manufacturing discipline as the National Science Foundation (NSF) funded the creation of Georgia Tech's Packaging Research Center, in 1994 To promote the development of semiconductor packaging theory and technology for the 21st century.

As a strategic basic industry, the scale and technical level of microelectronics industry have become one of the important signs to measure the comprehensive strength of all countries. Research data show that for each increase of 100,300 meters, the GDP needs electronic industry and integrated circuit output value of about 10 yuan. The contribution rate of integrated circuit to theof unit quality reinforcement to GDP is 1, car is 5, color TV and computer 1 000, while the contribution rate of integrated circuit is as high as 2000.

The development experience of developed countries in the world shows that the growth rate of the electronic industry is generally 3 times the GDP growth rate, and the integrated circuit growth rate is 2 times that of the electronic industry. According to incomplete statistics, in 1999, the consumption of some integrated circuits was RMB 43.6 billion, accounting for about 3.4% of the world's total integrated circuit sales. Take this as the basis, if the average GDP growth rate in China can be maintained at a rate of 5% and 6%, China's total integrated circuit sales will reach RMB 600 billion by 2010. Such a strong market demand has created a good development environment for electronic manufacturing.

At the rapid moment of information technology development in the 21st century, China 's computer enterprises and computer manufacturing science and technology are facing opportunities and challenges, scholars and researchers engaged in computer manufacturing

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science and technology research should conduct timely investigation and research, cooperate closely with relevant enterprises to study the key science and technology problems in computer manufacturing, in order to promote the rapid and healthy development of China' s information industry.

2. CHARACTERISTICS AND DEVELOPMENT TRENDS OF COMPUTER MANUFACTURING

Some distinct characteristics and development trends in the development planning and research direction of computer manufacturing in the world can be summarized as follows".

(1) Development to high performance, composite, multi-function, intelligent, integration and low cost; improved integration, product miniaturization, exquisite, functional composite, high power; product composite has good comprehensive performance.

(2) Pay attention to the design and preparation of new products at the molecular, atomic and electric isolation levels; based on the understanding of the multi-level law, establish the quantitative analytical relationship between the microstructure parameter and the macroscopic performance, establish the physical and mathematical model for numerical simulation, and establish the database expert system.

(3) Focus on the choice of materials. Recognizing that the key to ultimately determine the structure and control performance of materials and products is synthesis and processing, and to attach special emphasis on material synthesis and processing (preparation), the basic problem of electronic manufacturing industry is to develop new technologies and methods, improve the mature and controllable preparation technology, make the organizational performance of advanced materials stable and reliable, high finished rate, good repeatability, and the cost reduction.

(4) Pay attention to the interdisciplinary

crossover, the comprehensive use of the latest achievements of modern science and technology. Electronic manufacturing intersects with materials, mechanics, physics, chemistry, machinery, images, cybernetics, and informatics. Therefore, the design of electronic manufacturing equipment is an integrated system engineering. In the intersection of disciplines, the development of the electronic manufacturing industry itself and the development of other technical fields promote each other.

3. OPPORTUNITIES AND CHALLENGES IN DEVELOPING COMPUTER MANUFACTURING TECHNOLOGY

Computer computer industry is the main part of the information industry. Judging from the development trend of manufacturing globalization in the early 21st century, the competition of computer industry around product quality, price, delivery period and service is still inevitable. Computer technology grew faster than any other product. Competition among computer enterprises is characterized by globalization, networking, high-technology-intensive, labor-intensive and capital-intensive. Who has these advantages, who can win, just may not be eliminated by the market. As Asia and China have the advantages of the largest market and the cheapest labor, multinational computer companies are moving to the Asia-Pacific region, especially to coastal China. On the other hand, our own computer technology related enterprises are at a good time to build momentum and face good opportunities and severe challenges.

China has invested a huge amount of money in the development of China's integrated circuits and computers, but have failed to do so. Although China now has computer companies such as Lenovo Group, the key components in the computers, such as disk-drive components and chips,

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are basically foreign-made. Even China's chip production lines, its equipment and instruments, and even the whole production line are bought foreign. That is, we do not have the technology and equipment of world-class production computers.

There are many reasons for such results, such as planning economy and poor industrial foundation, but the author believes that there is another important reason for the backward science and technology related to computer manufacturing, especially the technology team and personnel engaged in manufacturing technology research have not invested into the research of computer manufacturing technology.

Figure 1. Hard-drive system

In computer manufacturing, the most representative technological level and the most key component is the manufacturing of chip and disk components. This paper presents the following views on scientific issues in the manufacturing of chip and disk components.

4. MICRO / NANO-BASED ON THE HEAD / DISK SURFACE AND INTERFACE DESIGN, PROCESSING, AND SURFACE MODIFICATION STUDIES

4.1. Development of the Hard Disk Drive System

Hard disk has become the main means of high-density storage with its advantages of high storage stability, fast transmission speed and high storage capacity. In particular, hard drives, in addition to numerous applications in computers, have begun to develop into the field of home appliances (such as cameras, cameras and video recorders, etc.) and will become an important device affecting human scientific research and daily life.

The storage and playback of hard disk information is primarily achieved in a high-speed rotational motion between the head and the disk. From a mechanical and fricricological point of view, relative moving heads and disks constitute a pair of motion pairs involving high accuracy, high speed motion control and positioning, microfriction and wear, surface processing and modification.

The disk drive system is shown in Figure 1. The key part of the hard drive is the head / disk component, which consists of disk groups and head stacks. The disc consists of a multilayer membrane structure. From inside to outside, generally: disk base, bottom layer, lining layer, magnetic layer, protective layer and lubrication layer.

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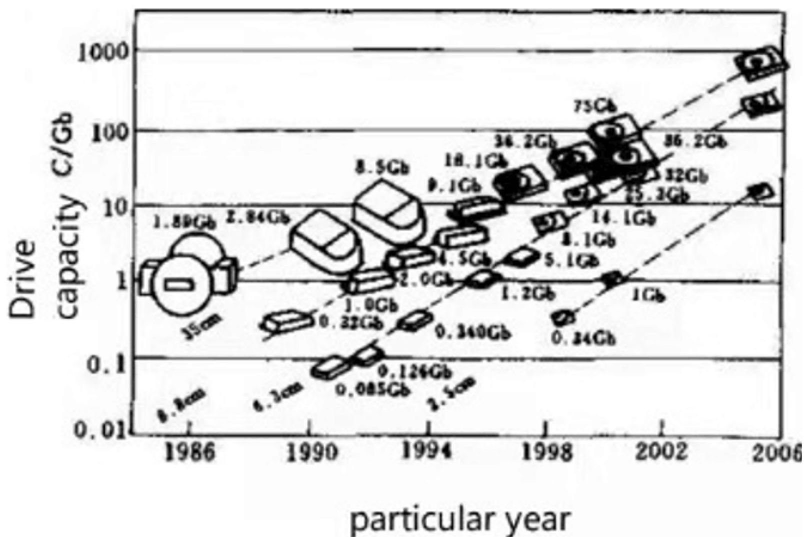

Figure 2. The relationship between hard disk size and storage capacity

Computer hard drives have developed very rapidly, both in size and storage. As shown in Figure 2, the 35 cm from the 19 80 s to the current 2.5 cm, storage grew from 1.89 Gb to over 75 Gb and gradually to 1 000 Gb. As can be seen from Figure 2, since 1991, the composite growth rate (Compound growth rate, CGR) of hard disk storage density (Compound growth rate, CGR) has increased at about 60% per year, even 100%, the increasing I% can be seen from Figure 3, and the flight height has decreased rapidly with the increase of magnetic storage density, while the flight control accuracy of magnetic head is constantly improving. It is expected that by 2002 the flight height will drop below 12 nm and the flight control accuracy will be about 3 nm. It is seen that improving magnetic storage mode and reducing head / disk clearance are the main factors affecting the rapid improvement of CGR.

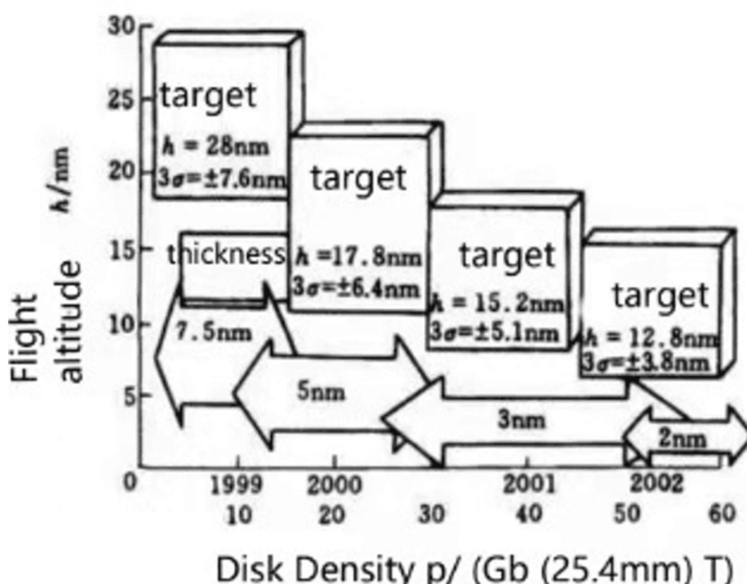

Figure 3. Relationship between flight height and storage density

There are two ways to reduce the magnetic gap: reducing the thickness of the lubrication film and reducing the flight height between the head / disk, the former facilitates preparation and materials studies based on the study of magnetic media protective film and the development of the head / disk from close contact reading (Proximity recording) to Pseudo-contact recording

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(Pseudo-contact recording). The development of head / disk technology requires head and disk wear at the " atomic scale, to achieve this, the conventional head / disk contact stop (Contact start/stop, CSS) approach has recently developed to the load / out (Load/ unload) approach. This technique prevents the heads to take off directly above them by contact with the disk, avoiding friction and wear during stopping between the heads / disks. However, it also increases the chance of disk impact when the head is loaded. Piepiezoelectric ceramic microdrive (PZT micro-acuator) plays a great role in promoting the channel accuracy and density of the head ', with the front signal chip located in the head support arm (Chip on suspension), improving the data transmission rate of the hard disk. However, they both affect the flight characteristics of the head and the search stability of the head because of changing the dynamics of the support arm, and the instability of the flight attitude will also cause friction and collision in the head / disk interface. Visible, the breakthrough of new technology brings some new problems.

With the rapid development of magnetic recording technology, the loss of lubricating molecules between the head / disk, the chemical stability of the lubrication layer and its external environment on the interface lubrication stabilityand the performance of the head / disk interface at the rapid rotation of the disk. The emergence and improvement of new experimental methods, such as various atomic scale-based surface analysis test instruments and theoretical analysis methods, further promote the deep development of nanomechanics, nanomaterials and nano-friction science of magnetic recording systems. The rapid development of the rapidly changing magnetic storage technology also poses more severe challenges to this research, and the interaction between the two promotes the rapid development of the computer level.

4.2. Nanometer-scale Modification Study of the Magnetic Head / Disk Surface and Interface

The study of hard drives is an interdisciplinary discipline integrating modern science such as magnetism, materials ology, fricbology, thin gas dynamics, high precision measurement, nanometer scale surface processing technology, high precision positioning technology and control technology. Increasing storage capacity is a comprehensive result of multiple technological advances. Today, with the rapid development of hard disk technology, the primary technology to drive hard disk to greater capacity, smaller volume, and cheaper direction is still head / disk interface technology, making research on head / disk-based surface and interface processing technology, modification technology, control technology and nanofriction technology become extremely active.

4.3. Subnanoscale Processing and Design Method of Magnetic Head / Disk Surface

4.3.1 Research on line characteristics and surface shape design

The reduction of magnetic gap between head / disks depends largely on the reduction of magnetic head flight height. The reduction of flight height not only puts forward higher requirements for the flight state and flight stability of the head itself, but also the inevitable collision between head / disks during ultra-low flight also puts higher requirements for the lubrication layer and protective layer.

The study of the flight characteristics of the magnetic head and the shape of the air cushion on Which tah fight is an important field. The head flying on the disk is similar to an air bearing. With the reduced flight height, the thinning effect of the lubricating gas is getting more and more significantly affected. With the continuous development of the magnetic recording technology, the head / disk gap is getting smaller and less, and the thinning effect of the lubrication gas (Rarefaction effect) is getting more and more significant, thus considering the lubrication of the head / disk interface.

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4.3.2 Homogeneous multicomponent surface nano-grade polishing technology

Computer head is a complex three-dimensional nanostructure. Its processing technology is more difficult than integrated circuits (two-dimensional manufacturing technology). As the flight height gradually developed below 10 nm, the roughness requirements of the head surface became smaller. The surface roughness is too large, on the one hand, scratches will destroy the structure of the reading head, lose its function; also due to the low flight height, rough surface or high surface will cause the disk; because the head surface protective film thickness is thin to 3 dishes, the rough surface will cause part of the protective film is too thin or unable to cover, resulting in corrosion, element diffusion and other problems. Therefore, with the reduction of flight height, the head surface subnanoscale polishing technology has become a key problem in the head manufacturing process. Nanoparticle polishing technology has greatly improved the surface appearance of the head, but there are still many problems to be further solved, such as extreme sharp subsidence, low grinding rate, uniform polishing of multi-group heterogeneous materials, fluid theory and polishing mechanism of nanosecond-phase flow.

4.3.3 Chemical I-Mechanical Polishing Technology (Chemical mechanical polishing, CMP)

With the rapid development of the semiconductor industry, driving the processing process is transferred to higher current density, higher clock frequency and more interconnection layer. Due to the reduction of the device size and the reduced focal depth of the lithography device, the flatness of the acceptable resolution of the processed substr5ate surface is required to reach the nanoscale. Traditional planarization techniques such as selective deposition, sputtering, LV CVD, plasma enhanced CVD, bias sputtering and deposition corrosion have been used in IC processes. However, although they can also provide "smooth" surfaces, they are all local planarization techniques and cannot achieve global planarization. Now, it is generally recognized that for chips with a minimum feature size of 0.35 " m and below, a global planarization must be performed, for which a new global planarization technology must be developed.

The new chemical mechanical polishing (CMP) technology which emerged in the 1990 s simultaneously met the processing requirements of wafer shape such as Wafer in terms of processing performance and speed. CMP technology is a combination of mechanical grinding and chemical corrosion, forming the polished and smooth surface circle with the grinding action of ultra-microparticles and the chemical corrosion action of the slurry.

4.3.4 Subbeam polishing technology

Ion beam polishing technology is a polishing technology developed from ion beam etching. Its basic principle is to bang the surface with an ion beam of certain energy, so as to achieve the purpose of leveling the surface. The ion beam polishing effect is mainly related to the ion beam energy, angle of incidence and polishing time. It is shown that ion beam polishing is related to energy, time and angle and the initial appearance of the thrown surface. For the rougher surface, the ion beam polishing effect is obvious, but for the very smooth surface, such as my sleeve O. lnm surface, the ion beam before and after the polishing, the roughness is basically no change. However, ion beam polishing is the key to research.

4.4. New Challenges in Mechanics from the Development of Magnetic Storage and Semiconductors

The rapid development of hard disk and chip technology has brought endless problems to the related research fields. Serious challenges to materials, mechanics, frictional, and molecular dynamics. When the magnetic storage density reaches 100 Gb/(25.4mm)2The magnetic gap should drop to about 8 nm, the thickness of disk protection layer should be reduced to 2 nm, extreme tip shrinkage from 3 nm to 1 nm, therefore bound to bring more friction and wear of disk / magnetic, increased loss of disk lubrication molecules, stable head flight attitude,

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chemical corrosion of magnetic media, surface supermachining, aerodynamic simulation of molecular scale gap, high-precision rotation control and positioning of disk, harm of surface micro pollution. Therefore, the research from the two aspects of surface modification technology and theory and surface nanoscale processing and design technology and theory, will have an important value and impetus in the field of semiconductor manufacturing, such as computer heads and chips.

5. SCIENTIFIC PROBLEMS IN POST-CHIP PACKAGING MANUFACTURING

Over the past 10 years, due to the shrinking volume of consumer products, the chip and its packaging size have gradually shrunk, and the function has become stronger and stronger. With the development of microelectromechanical products (MEMS) and system chip (System on chip), the spacing between chip wiring and the diameter of the welding ball have been decreasing, proposing new requirements for the accuracy, reliability and speed of packaging equipment and devices, and the design of encapsulation equipment requires comprehensive knowledge of interdisciplinary crossing.

At present, most IC manufacturing enterprises in China are still mainly material processing and production methods, in the increasingly international competitive market, the lack of cutting-edge technology with independent copyright. Production equipment is relatively backward, and key equipment depends on imports. For example, the large use of bonding machines and bonding machines, China can not be produced at present. China has solved the temporary problem of the initial development of electronic manufacturing industry. However, to develop IC post-packaging equipment with market competitiveness and independent intellectual property rights, it is urgently necessary to study new manufacturing theories, technology and manufacturing equipment Advanced process control for IC packaging.

The packaging of the IC chip involves complex processes such as non-Newtonian fluid flow, heat conduction, and high-precision mixing force / position real-time control (bonding). In the process of chip bonding, because the glue used in IC packaging (mostly epoxy resin) is a non-Newtonian fluid, its complex and changeable properties make it difficult to ensure the performance and quality of the bonding with conventional technology. How to model and precise shaping control of IC droplet process has become one of the recognized problems in the packaging process. With the continuous shrinking scale of semiconductor chips, microheat transfer and strong transient heat transfer will become the leading role, and the traditional thermal transfer analysis and design methods have been unable to meet the requirements. The thermal-force coupling produced by this special temperature field directly affects the mechanical properties and packaging quality of the chip, so it is necessary to study the strong transient micro-heat transfer and its thermal-force coupling theory and numerical simulation methods. The new generation of chip lead bonding equipment requires the welding operation within 1ms after the contact between the lead and the disc. The key lies in the design and precision force control, and how to improve the hybrid force / position control theory and system have become very important. The research in this direction includes the following issues.

(1) Analysis and modeling of non-Newtonian fluid in IC bonding process; modeling method for distributed parameters design and control; establish theoretical system for accurate formation of non-Newtonian fluid.

(2) The temperature field modeling and control of the heat transfer process.

(3) Packaging process precision force sensor research and high-precision mixing force / position real-time control.

(4) Effective surface contact models and microoperating theoretical systems at microscales.

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5.1. Reliability Analysis and Prediction Model of Packaging Quality

5.2. Theory of Precise Positioning of High Acceleration (Greater Than 10g) High Frequency (Greater Than 10 Times Per Second) Motion Systems

Interinterconnection of chip I/O line is the most critical link of semiconductor packaging, how its quality determines the performance of the 40 groans and 15 line / s, and are still in further development, predicting that the next-generation IC rear package equipment must have high speed positioning accuracy of 10-300 nm. High precision and high productivity are contradictory: high precision positioning hopes to achieve smooth equipment movement, and high speed reciprocation movement and high speed shutdown. How to better solve this contradiction and realize the precision positioning of high acceleration and high frequency mechanical movement system has become an urgent problem to be solved. Precision positioning is a comprehensive technology, including the visual positioning and motion positioning, where the visual positioning provides the motion target position, and the motion positioning realizes the corresponding mechanical motion.

The motion positioning precision is determined by three parts: mechanical static precision (geometric error, thermal deformation, load deformation), mechanical dynamic precision (vibration) and servo control precision. In the fields of machine tools and robots, the error compensation method is usually used to reduce the static error and achieve high precision tasks with low precision equipment. Because the packaging equipment itself is a high precision equipment, how to measure the small static error and identify the parameters of the error model is a big problem. High acceleration and wide band vibration brought by rapid start and stop of packaging equipment bring many problems to positioning, product quality and equipment life. Supvibration of positioning system in a very short time (within 10ms) has been a problem troubling the packaging circle. Looking for high damping materials, optimizing system structure and damping position, shape and number to reduce high frequency vibration. Active control of low frequency vibration of positioning system is the main research route using actuator and control system. In the high-precision servo control, the influence packaging product.

Interconnection technology includes several key production processes, such as chip bonding, lead bonding, etc., which require the equipment to have high positioning accuracy, spatial movement accuracy and productivity, and the indicators that can be achieved are 25 groans, respectively of uncertainties such as nonlinear friction and transmission clearance error cannot be ignored. How to design a high-performance controller and identify and compensate the uncertainties of the control system has become a hot spot and difficulty in the current high-speed servo control research. Since the static error depends on the manufacturing accuracy of the device and the form of institutional movement, and the design of the dynamic error and the controller depends on the dynamic behavior and movement trajectory of the device, the influence of these factors should be considered comprehensively during the equipment design stage. The current research focus in this direction focuses on the following issues.

(1) Integrated design theory of high acceleration, high frequency and high-precision mechanical motion system.

(2) Analysis method of flexible microdisplacement structure and kinematics and dynamics modeling theory.

(3) Uncertainty modeling of high speed, large displacement, superprecision, and strong robustness control of motion systems.

(4) Theory of micropositioning and control of manufacturing process based on real-time machine vision information.

(5) Adaptive vibration damping mechanism and method.

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6. CONCLUSION

This paper presents some key scientific and technical problems in computer disk drive and chip manufacturing, which are mostly related to materials, information, physics, mathematics and chemistry. In the beginning of the early 21st century, we must strongly support the basic research in this field. Its importance not only broadens and develops the traditional manufacturing industry, but also is an urgent8 Journal of Mechanical Engineering demand for the healthy and sustainable development of our national economy. The difference between computer manufacturing and traditional manufacturing is that it is an advanced electronics, through the mechanics, materials, control theory, information and molecular dynamics, can establish the advanced electronic manufacturing and the theoretical and experimental prototype system, for the development of the electronic manufacturing industry and the training of senior research and development personnel.

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