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Reform on the "Foundation-level" Talents Cultivation and Teaching Model in the Integrated Circuit Industry

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Abstract: A survey was conducted on the development of the integrated circuit industry and talent demand in Fujian Province. Based on the analysis of the industry development trend and the current status of talent cultivation, the typical job tasks and professional abilities of the "foundation-level" talents in the integrated circuit industry, which are concentrated in the wafer manufacturing industry, chip packaging and testing industry, were analyzed. The deficiencies of the existing teaching model were pointed out, and the exploration and implementation of "foundation-level" talent cultivation and teaching mode reform in terms of curriculum reform and optimization, school-enterprise cooperation, integration of production and education, teacher team construction and cultivation, and the construction of practical teaching platforms were carried out, which achieved significant results and have the value of being promoted in similar vocational colleges.

Keywords: Integrated circuit; Wafer manufacturing; Packaging and testing; Talent cultivation; Teaching mode

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1. Introduction

The integrated circuit (IC) industry serves as a strategic cornerstone for national economic development, playing a vital role in safeguarding national security and leading a new round of technological and industrial transformations [1]. In recent years, China's IC industry has flourished, benefiting from national policy support. The National IC Industry Development Promotion Outline, released in 2014, clarified the development direction, emphasizing technological breakthroughs in design, manufacturing, packaging, and testing, as well as key equipment and materials. In 2020, further policies were introduced to optimize the development environment and enhance innovation capabilities. In 2023, China's IC production increased to 351.4 billion units, up 6.9% year-on-year, demonstrating resilience and potential amidst a global downturn in the industry. It is estimated that the annual compound growth rate of China's IC market size will reach 9.2% by 2025, indicating the continuous growth of the industry in the future.

2. Current development status of Fujian's IC industry

In recent years, Fujian Province has been fully developing its IC industrial cluster, forming a spatial layout of "One Belt, Two Cores, and Multiple Parks," encompassing the coastal industrial belt spanning Fuzhou, Putian, Quanzhou, and Xiamen, with Xiamen and Quanzhou as the cores, complemented by industrial parks in various regions. Fuzhou, Xiamen, Quanzhou, and Putian are the main hubs of the IC industry chain. Fuzhou and Xiamen have formed relatively complete IC industry chains, while Quanzhou is extending its industry chain through multiple project constructions. Putian, led by Jiemu Technology, has ventured into multiple fields. Fujian also actively promotes cooperation with Taiwan to jointly drive the development of the IC industry [2].

In terms of wafer manufacturing, Fujian possesses high technical standards. United Microelectronics Corp. (Xiamen)'s first fully automated 12-inch wafer production line has been continuously expanding its capacity, while Jinhua Integrated Circuit has nano-scale memory chip manufacturing processes. In the field of packaging and testing, Fujian has also maintained steady growth, with projects such as SPIL (Fujian) and the wafer testing platform of the Xiamen Free Trade Zone National "Core Fire" Innovation and Entrepreneurship Base, which have filled the gap in IC wafer testing within the province and optimized the industrial ecosystem [3].

3. Current status of IC industry talent in Fujian

The IC industry has high educational requirements for talent, typically requiring an associate degree or above. 13 undergraduate institutions in Fujian offer related majors, with enrollment numbers gradually increasing. For instance, from 2016 to 2020, the undergraduate enrollment in these majors increased from 1,985 to 2,244 students [4]. However, only 20% of graduates enter the industry. Vocational college training is almost non-existent, resulting in limited talent supply. The severe talent gap has become a bottleneck for industry development. This survey targeted mainstream job recruitment websites in Fujian Province, collecting job information from 167 enterprises with 325 positions, categorized into chip design, wafer manufacturing, and packaging and testing. The results showed that chip design accounted for 48.92% of the demand for entry-level positions, while manufacturing and packaging accounted for 51.08%.

4. Typical job tasks and professional competencies for IC manufacturing and packaging & testing talent

Based on enterprise job surveys and analysis, the main typical job tasks for fresh graduates from vocational colleges in IC manufacturing and packaging & testing positions are as follows:

In the field of wafer manufacturing, wafer assistant engineers, process assistant managers, operators, and engineers each have their responsibilities. Assistant engineers assist engineers in improving yield rates, maintaining documentation, introducing mass production processes, and handling abnormalities. Managers handle materials receiving and dispatch, inventory checks, work order processing, and scrap disposal. Operators are responsible for daily production, measurement operations, and data statistics, while also assisting in improving product yield rates and managing production lines. Engineers are responsible for formulating technical documentation, debugging processes, introducing new processes, and improving yield rates [5].

In packaging and testing, packaging and testing engineers design testing schemes, formulate testing plans, monitor product defects, and solve technical problems. Electronic assistant engineers assist in project circuit design and debugging, participate in product development testing, possess welding foundations, and can proficiently weld components. They also assist in project transfer to production and provide technical guidance to production lines. Each position collaborates closely to efficiently drive the wafer manufacturing and packaging and testing processes.

Based on enterprise job surveys and analysis, the required professional competencies for fresh graduates from vocational colleges in IC manufacturing and packaging & testing positions are as follows:

In the field of wafer manufacturing, positions include wafer assistant engineers, wafer process assistant managers, wafer operators, and wafer engineers. Assistant engineers and managers assist engineers in improving yield rates, handling mass production introductions, and production abnormalities. Assistant engineers are also responsible for the routine maintenance of equipment lines. Operators handle daily production operations, wafer measurements, and data analysis. Wafer engineers require a relevant professional background and knowledge of wafer processing [6,7].

In packaging and testing, packaging and testing engineers need to master hardware layout, be familiar with software development languages such as LabVIEW/C++, and understand chip testing principles. Electronic assistant engineers need to be familiar with hardware circuit welding, debugging, and testing, possess circuit board design capabilities, and be proficient in operating electronic design software. In addition, they assist in project transfer to production and provide technical guidance to production lines. Each position requires attention to detail and patience to ensure efficient production processes and product quality.

Through survey analysis, the future demand for talent in the IC industry tends towards high professionalism [8], requiring students to have a strong sense of identity and long-term aspirations. The entry barriers for each link vary, but graduates with professional education and vocational skills are more favored by enterprises.

5. Deficiencies in existing training modes

The cultivation of talents in the integrated circuit (IC) industry is characterized by high thresholds, a wide range of fields, and a long cycle, necessitating the establishment of a comprehensive talent system spanning from the “peak” to the “base” of the pyramid. Often, the external focus is excessively directed at “peak” design talents while neglecting “base” manufacturing and packaging and testing talents, who are crucial for industry development. Taking packaging and testing as an example, China’s mainland has already gained a scale advantage; however, the insufficient quantity and quality of “base” talents will impact the rapid development of the industry. According to survey results, there are numerous issues in the current cultivation of “base” talents in the IC industry [9].

5.1. Unreasonable talent cultivation objectives and curriculum systems

The talent cultivation objectives and curriculum systems of vocational colleges are broad and lack specific direction. The rapid expansion and high confidentiality of the IC industry restrict the widespread dissemination of professional knowledge and skills, leading to narrow course and textbook content and simplistic teaching methods. This makes it difficult for teachers and students to access the latest industry knowledge and gain an in-depth understanding of critical information about advanced equipment, posing a significant challenge to the cultivation of highly skilled talents.

5.2. Lack of experienced teachers in the industry

IC majors require teachers with rich industry experience and engineering practice abilities, but local vocational colleges generally face a shortage of teachers. Due to inadequate salaries and limited access to cutting-edge technological information, it is difficult to attract industry elites. Most existing teachers have recently graduated from universities and, while experienced in scientific research, lack industrial practice. Teaching emphasizes theory over practical activities. This results in students relying heavily on textbook knowledge, with a large deviation between their practical abilities and industry demands, making it difficult to meet the talent requirements of the IC industry.

5.3. Lack of practical training facilities

In the IC industry, the high cost of chip manufacturing, packaging, and testing equipment poses challenges for local vocational colleges in building experimental and practical training facilities. Establishing production lines through school-enterprise cooperation is difficult to promote due to high maintenance fees. The lack of good practical training conditions makes it difficult for students to gain an in-depth understanding of equipment and operational experience, leading to the high-skilled talent cultivation goal being difficult to achieve and remaining at the theoretical level, unable to meet industry demands.

6. Reforms in IC "base" talent cultivation and teaching modes

6.1. Curriculum reform and optimization

Based on industry surveys, the curriculum system for the Electronic Information Engineering Technology specialty was adjusted, divided into Flexible Electronics, Intelligent Electronics, and IC Technology directions, with 3–4 job capability courses set for each. The IC direction focuses on manufacturing and packaging & testing positions, covering manufacturing processes, packaging and testing technologies, etc., closely aligning with industry demands and core job responsibilities.

The curriculum setting aligns with IC industry demands, achieving a match between the curriculum system and job tasks, course content and professional abilities, learning scenarios and work scenarios. Teaching design emphasizes practical operation and skills training, adopting a "work-process-based, project-oriented, theory-practice integration" approach, introducing an IC manufacturing virtual simulation platform to realize "integration of teaching, learning, and doing." The teaching mode is mainly "project-guided, task-driven," utilizing various teaching methods, emphasizing the introduction of new technologies and processes, and cultivating students' career development abilities [10].

6.2. School-enterprise cooperation and industry-education integration

The Information Engineering College of our school has explored a new "dual-system" talent cultivation mode with Xiamen IC-related enterprises such as Xiamen United Microelectronics Corp., Tongfu Microelectronics, and Silan Microelectronics [11], aiming to provide the enterprises with directionally trained IC talents for mutual benefit. The school and enterprises jointly established pilot work institutions responsible for operational management and problem-solving. Specific cooperation includes: transforming teaching methods to adopt a "dual-subject school-enterprise, work-study integration" mode; reconstructing the curriculum system, jointly formulating teaching plans, and developing textbooks integrating professional knowledge and safe operating skills; strengthening practical training sessions, formulating assessment standards, and promoting practical problem-oriented internships and practical training; highlighting the responsibilities of enterprise mentors, selecting outstanding technical personnel to serve as mentors responsible for apprentice job skill training, undertaking more than 60% of practical course teaching tasks.

6.3. Construction and cultivation of the teacher team

To serve the construction of the IC specialty, the specialty has introduced multiple high-level talents with more than 15 years of industry experience to form a teaching team with in-school full-time teachers. Relying on these talents, scientific research, teaching research, and enterprise exchanges have been strengthened to track new technological trends. Teachers from the college founded an IC company, which has won multiple honors and has become a listed backup enterprise. Schools and enterprises have deeply explored the integration of industry and education, innovated collaborative education mechanisms, and strengthened teacher practice and talent cultivation.

6.4. Construction of practical teaching platforms

Addressing the current lack of practical training facilities for IC industry talent cultivation, the school has improved its in-school practical training bases and constructed an IC virtual simulation and testing center [12–15]. At the same time, it has undertaken the Ministry of Education's "Supply-Demand Matching for Employment and Education" project, reforming teaching modes in three aspects: virtual simulation practical training to simulate actual job skill operations; actual equipment operation combined with virtual-real integration, using industrial-grade testing equipment for chip testing; and developing teaching resources and evaluation standards to help students grasp experimental content and understand teaching effects. These initiatives aim to enhance students' practical abilities and comprehensive qualities to adapt to the demands of the IC industry.

7. Evaluation of reform effects and outlook

The school has centered its efforts around the development of the IC industry, incorporating professional standards into talent cultivation, achieving remarkable results and wide recognition from social enterprises. Students have repeatedly excelled in skills competitions and innovation and entrepreneurship activities, and the teacher team has played a prominent role in industrial services, including guiding students to win more than 8 provincial-level skills competitions, completing 21 projects and research topics, obtaining more than 30 patents, and cooperating with enterprises to carry out modern apprenticeship programs, completing training for over 1,000 people. In the future, our school will continue to deepen reforms in talent cultivation and teaching modes, improve the quality of vocational education, realize a seamless connection between training objectives and market demands, establish a distinctive vocational undergraduate specialty, cultivate more high-quality talents that meet the development needs of the IC industry, and contribute to the sustainable development and innovation of the industry.

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