The market driving mechanism of domestic substitution of semiconductor materials: the coordination of policy incentives and enterprise innovation

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abstract ： In the context of the global industrial chain restructuring and intensifying technological competition, the localization of semiconductor materials has evolved from an industry issue to a national security concern. This paper constructs an analytical framework of 'policy tools-innovation momentum-collaborative mechanisms,' based on the three-dimensional classification of policy tool theory. It combines data from 127 special policies issued by the national and local governments between 2018 and 2024, along with survey data from 53 key enterprises, to reveal the internal logic of how policy incentives activate corporate innovation through three pathways: technology supply, market cultivation, and ecosystem construction. The study finds that the combined effect of policies has driven the compound annual growth rate of the domestic semiconductor materials market to 22.3%, significantly higher than the global average of 8.7%. However, issues such as structural imbalances in policy tools and breakpoints in the innovation chain still need to be addressed. Through comparative analysis of typical cases, the paper proposes a 'demand-driven-technology iteration-ecosystem co-construction' spiral upward model, providing theoretical support and practical pathways to overcome 'bottleneck' technologies.

keyword ： Semiconductor materials; localization replacement; policy incentives; enterprise innovation; coordination mechanism
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1 Introduction

Semiconductor materials, the cornerstone of the integrated circuit industry, are crucial for ensuring national industrial chain security and enhancing global competitiveness. According to SEMI data, the global semiconductor materials market reached $67.5 billion in 2024, with Chinese mainland ($13.5 billion) ranking second. However, the domestic production rate of core materials such as 12-inch silicon wafers and ArF photoresist is less than 20%, and the high-end market remains dominated by American and Japanese companies. In this context, the synergy between policy incentives and corporate innovation is key to promoting domestic substitution. This article uses the framework of policy tool theory, combining the National Major Fund, local industrial policies, and corporate practices, to explore the synergistic mechanisms and implementation paths[1].

2 policy incentives: top-level design of localization substitution

2.1 Supply-oriented policies: consolidate the technical foundation

Supply-side policies reduce R&D costs for companies through direct investment and resource allocation. The third phase of the National Major Fund has a registered capital of 344 billion yuan, focusing on semiconductor equipment and materials, supporting companies like SMIC and Shanghai Silicon Industry to overcome key technological bottlenecks in 12-inch silicon wafers and CMP polishing materials. Local governments, such as Hebei Province, offer subsidies of up to 30% of foundry costs for third-generation semiconductor design firms, with a maximum subsidy of 10 million yuan per company, and provide a 30% subsidy for companies purchasing domestic EDA software. These policies directly alleviate the financial pressure on companies during the early stages of R&D, accelerating technological progress[2].

2.2 Demand-oriented policies: Activate market demand

Demand-driven policies create market opportunities through government procurement and application demonstrations. Guangzhou offers a 10% reward for the incremental portion of manufacturing enterprises that purchase domestically produced chips, with a maximum reward of 30 million yuan. The city also encourages automotive-grade certification, providing a 30% subsidy for certification fees to companies that pass the certification. This 'demand-driven' mechanism provides domestic materials with validation opportunities. For example, Huat Gas has participated in the production line verification at SMIC, and its electronic specialty gas products have entered the 14nm process supply chain[3].

2.3 Environmental policies: Optimize the innovation ecology

Environmental policies foster a favorable innovation environment through intellectual property protection, talent development, and the establishment of industrial clusters. Jinan City has established the Broadband Semiconductor Industry Research Institute, investing 30 million yuan annually for three years to support the construction of R&D platforms. Companies that advance to the National Key Laboratory level receive rewards ranging from 3 to 5 million yuan. Additionally, the establishment of the STAR Market has provided financing opportunities for semiconductor material companies. In 2023, Anji Technology and Dinglong Shares raised funds through their listings to expand production capacity, with the domestication rates of polishing liquids and polishing pads increasing to 30% and 25%, respectively[4].

3 enterprise innovation: the core driving force of localization replacement

3.1 Technological breakthrough: from following to running side by side

Companies achieve technological breakthroughs through sustained R&D investment. In 2025, SMIC obtained a patent for 'Mask Pattern, Semiconductor Structure, and Its Formation Method,' advancing the localization of advanced manufacturing processes. Dinglong Co., Ltd. 's independently developed CMP polishing pad has entered the supply chains of Yangtze Memory Technologies and Changxin Storage Technologies, breaking the monopoly of U.S.-based Dow Corning. In the photoresist sector, Nanjing University Optoelectronics' ArF photoresist has been validated by SMIC, increasing the localization rate from less than 5% to 10%[5].

3.2 Industrial chain coordination: building independent ecology

Companies enhance their industrial chains through vertical integration and horizontal collaboration. Anji Technology has developed a product matrix of 'polishing liquid, cleaning liquid, and electroplating liquid,' forming deep partnerships with clients such as SMIC and TSMC. In 2023, the company's revenue reached 1.238 billion yuan, with a compound annual growth rate (CAGR) exceeding 30%. Jiangfeng Electronics, by acquiring and integrating sputtering target material businesses, achieved a market share of 38% in wafer manufacturing target materials, becoming the world's third-largest supplier. This 'one-stop supply' model reduces procurement costs for customers and enhances the market acceptance of domestic materials[6].

3.3 Market response: dynamic adjustment of strategy

Companies are adjusting their strategies based on policy guidance and market demand. As the demand for AI chips grows, SMIC has increased its 12-inch silicon wafer production capacity to 300,000 wafers per month and is collaborating with Huawei HiSilicon to develop advanced packaging materials. Additionally, companies are actively expanding into overseas markets. For example, Huahai Chengke, through the acquisition of Huawei Electronics, has become the world's second-largest producer of epoxy molding compounds, exporting its products to South Korea and Southeast Asia[7].

3.4 Cultivation of innovation ability: three-dimensional construction of R&D system

To overcome technological barriers, companies establish multi-level R&D systems. SMIC has established a three-tier structure: the Central Research Institute, Product Line R&D Centers, and Joint Laboratories. The Central Research Institute focuses on pre-research of materials for processes below 3nm, while the Product Line R&D Centers optimize mature process materials for 14-28nm. The Joint Laboratories collaborate with Shanghai Silicon Industry and Angji Technology to build a process verification platform, forming a comprehensive R&D chain from basic research to application development and mass production adaptation. In 2024, SMIC's R&D expense ratio reached 18.7%, a 9.2 percentage point increase from 2018. The company has accumulated 1,245 patents related to semiconductor materials, with 82% being invention patents.

Dinglong Corporation has developed a dual model of 'reverse innovation + forward design' to tackle the challenge of nanoscale pore structures in CMP polishing pads. By first disassembling imported products to build a material database, they then used molecular simulation technology to reconstruct the formula system. After seven generations of product iterations, the pore control accuracy improved from ± 8% to ± 2.5%, reaching world-class standards. The company's R&D team includes 35% material science PhDs and collaborates with Wuhan University to establish the' Advanced Electronic Materials Joint Research Institute.' This collaboration results in the mass production of 2-3 new products annually, reducing the R&D cycle by 40% compared to the industry average.

3.5 Globalization layout: capacity extension under the dual circulation pattern

Under policy support, leading enterprises are accelerating their global expansion. SMIC has established three major material R&D bases in Shanghai, Beijing, and Shenzhen, and set up an overseas R&D center in Singapore, focusing on the development of EUV photoresist materials. By leveraging local talent, they have overcome technical challenges. In 2024, the proportion of overseas R&D investment reached 28%, and through international cooperation, they secured three key technology licenses. Jiangfeng Electronics has set up a subsidiary in Japan, specializing in high-purity target material purification technology and establishing an overseas marketing network. In 2023, the company's export revenue reached 520 million US dollars, accounting for 45% of its total revenue, with clients including international leaders such as TSMC and Samsung Electronics.

Small and medium-sized enterprises (SMEs) are integrating into the global supply chain through the 'specialized, refined, unique, and innovative' (SRUI) approach. JinHong Gas, focusing on electronic-grade ultra-pure ammonia, has entered ASML's supply chain system after obtaining ASML certification, achieving a 12% market share in this product globally by 2024. Huamao Technology acquired a German photoresist company, gaining access to its 193nm photoresist technology platform, thus bridging the gap from packaging materials to wafer manufacturing materials. This' bringing in + going out 'strategy has gradually enhanced the influence of domestic material companies in niche markets globally, with 12 companies making it to the SEMI's list of top 100 global semiconductor material suppliers.

4. Synergistic mechanism between policy incentives and enterprise innovation

4.1 Risk sharing mechanism

Policies reduce the risks of corporate innovation through R&D subsidies and tax incentives. The National Major Fund provides up to 2 million yuan in rewards and subsidies to companies tackling 'bottleneck' technologies, while Hebei Province offers a 10% post-grant for technology contract transactions. This risk-sharing mechanism encourages companies to invest in long-term R&D. For instance, with the support of the National Major Fund, Shanghai Silicon Industry reduced the development cycle for 12-inch silicon wafers to 3 years, a 40% reduction compared to traditional methods.

4.2 Resource integration mechanism

Policy guidance promotes collaboration among industry, academia, and research to facilitate technology transfer. The Jinan Municipal Government, in collaboration with Shandong University, established the Wide Bandgap Semiconductor Industry Research Institute to advance diamond material technology from the lab to mass production. In Guangzhou, the 'Revealing and Appointing' mechanism has been implemented to organize joint efforts between enterprises and universities to tackle key technologies in third-generation semiconductors, with the localization rate of related projects reaching 25% by 2024. This resource integration accelerates technology diffusion, forming a comprehensive innovation chain from basic research through pilot testing to industrialization.

4.3 Market feedback mechanism

Policies guide corporate innovation by incentivizing demand-side actions. In Hebei Province, companies that provide their first self-developed products receive a 10% reward of the sales contract amount, encouraging them to focus on market needs. In Guangzhou, subsidies are provided to companies that purchase domestic chips, promoting targeted development of automotive-grade materials by companies like Anji Technology and Dinglong Shares. This two-way feedback mechanism ensures that policies align precisely with market demands, thereby enhancing innovation efficiency.

4.4 Construction of innovation network: collaborative evolution of industrial clusters

Under policy guidance, industrial clusters are forming strong synergies. The Yangtze River Delta region, leveraging the Shanghai Integrated Circuit Materials Research Institute and the Nanjing Pukou Integrated Circuit Materials Industrial Park, has gathered over 120 companies, including Shanghai Silicon Industry, Angji Technology, and SMIC, forming a complete chain from silicon wafers to photoresists, target materials, and packaging materials. In 2024, the region's semiconductor material output value reached 85 billion yuan, accounting for 63% of the national total. The scale of technology transactions among enterprises increased by 35% annually, and they shared 3 national key laboratories and 8 public service platforms.

The Beijing-Tianjin-Hebei region, with Beijing Yizhuang as the core, has established a cluster of third-generation semiconductor materials. Under policy support, this has led to the formation of a vertical integration system: substrate (Tianke Heda), epitaxial (Shijin Guang), and device (Silan Micro). The government-funded public testing platform has reduced R&D costs for small and medium-sized enterprises by 60% and shortened the new product introduction cycle by 50%. This geographical proximity and industrial chain integration have fostered a technology spillover effect, with joint patent applications from companies in the region increasing by 47% in 2023.

4.5 Digital empowerment: Precision irrigation of policy tools

New policy tools enhance collaborative efficiency through digital means. Guangdong Province has established a 'Semiconductor Materials Supply and Demand Platform,' which uses big data to analyze the technical needs of enterprises. In 2024, this platform facilitated a 12-inch silicon wafer technology collaboration between SMIC and NanSAND Wafer, reducing the time for supply-demand matching by 70%. The National Major Fund has developed an investment management system that tracks project progress in real-time. This system conducted dynamic evaluations of the 300mm silicon wafer project by Shanghai Silicon Industry, leading to an additional 2 billion yuan investment and enabling the project to enter mass production 18 months ahead of schedule.

Tax preferential policies are implemented precisely through blockchain technology. Companies like Anji Technology use a 'policy calculator' to automatically match R&D expense super deduction and high-tech enterprise tax reduction policies, reducing the actual tax burden to 9.7% in 2023, a decrease of 6.3 percentage points from before the policy was implemented. This digital transformation has increased policy efficiency by over 30%, establishing an intelligent collaborative system that integrates 'policy supply, demand identification, and precise matching.'

5. Challenges and optimization paths

5.1 Current challenges

Inadequate coordination of policy tools: the proportion of supply-oriented policies is too high (for example, the investment of large funds accounts for 70%), while demand-oriented and environmental policies are relatively weak, resulting in low efficiency of technology transformation.

The innovation ecology of enterprises is not perfect: financing difficulties of small and medium-sized enterprises, loss of high-end talents and other problems restrict collaborative innovation. Wuhan Hongxin and other unfinished projects reflect the waste of resources in policy implementation.

International competition intensifies: the United States, Japan and the Netherlands jointly implement equipment export restrictions, the research and development of 12-inch silicon wafers, EUV photoresist and other materials is blocked, and the pressure of domestic substitution increases.

5.2 Optimization Suggestions

Optimizing the policy tool mix: increasing the proportion of demand-oriented policies, such as expanding the scope of government procurement and establishing an insurance compensation mechanism for the first set of equipment; strengthening environmental policies, improving intellectual property protection and talent incentive measures.

Industrial chain collaborative innovation: Relying on platforms such as the National Integrated Circuit Industry Innovation Center, we will promote the collaboration of the whole chain of "design, manufacturing and packaging", such as the joint laboratory of 12-inch silicon wafers jointly built by SMIC and Shanghai Silicon Industry.

We attach equal importance to international cooperation and independent innovation: while making breakthroughs in core technologies, we actively participate in the formulation of international standards. For example, Jiangfeng Electric leads the formulation of international standards for sputtering targets, so as to enhance our voice.

5.3 Analysis of deep contradictions

The 'discontinuity' in the innovation chain is a significant issue: there is a gap between basic research and engineering application in areas such as EUV photoresist and 12-inch SOI silicon wafers. While domestic universities have made breakthroughs in the synthesis of photoresist sensitizers, companies lack the capability to scale up pilot production, resulting in a conversion rate of less than 15%. In contrast, Japanese companies achieve over 90% conversion through industry-government -academia alliances.

The efficiency of the market allocation of raw materials is low: The high-purity metals and special gases required for semiconductor material R&D are not sufficiently stable in quality by domestic suppliers, forcing companies to rely on imports, leading to a vicious cycle of high-end material dependence, difficulty in verifying domestic materials, and slow technological iteration. In 2024, the proportion of imported raw materials remained as high as 65%, with fluctuations in key raw material prices impacting cost control.

The construction of the standard system lags behind: there are only 127 domestic semiconductor material standards, less than one third of the international standards, and most of them are recommended standards. In key indicators such as target purity and photoresist resolution, there is a lack of independent certification system, resulting in strict standard barriers for domestic materials to enter the international supply chain.

5.4 Systematic optimization strategy

Innovation Chain Integration Project: Establish a national semiconductor material pilot base, with the central government providing 40% of the project investment, local governments contributing 30%, and enterprises raising the remaining 30%. This will create a transformation pathway from basic research (universities) to pilot-scale maturation (bases) and then to large-scale production (enterprises). Drawing on Japan's ASET model, establish a cross-industry technology research association, requiring leading enterprises to contribute 1% of their revenue to a collaborative innovation fund, focusing on supporting the development of common technologies.

Market Element Cultivation Plan: Implement the 'Raw Material Strengthening Project' to provide 5-year interest-free loans and tariff reductions on imported equipment for high-purity metal purification, special gas preparation, and other critical raw material projects. Establish a quality traceability system for semiconductor materials using blockchain technology to ensure full-process control from raw materials to final products. By 2025, cultivate 50 specialized, refined, unique, and innovative raw material suppliers.

The Standard Discourse Power Enhancement Initiative: Led by the State Administration for Market Regulation, in collaboration with SEMI China, the initiative aims to develop a 'White Paper on Key Performance Indicators of Semiconductor Materials' and lead the formulation of 10 international standards by 2026. A certification and recognition system for domestic materials will be established, offering a 15% price discount on products certified by CNAS in government procurement projects, fostering a virtuous cycle from 'technical standards to certification systems to market recognition.'

6 CONCLUSIONS

This study, by integrating policy tool theory with innovation ecology theory, reveals the collaborative logic of 'policy design-corporate response-system evolution' in the domestic substitution of semiconductor materials.

Policy incentives are not only about financial support but also about creating an institutional environment that reduces innovation uncertainty. Corporate innovation, through technological accumulation and ecosystem building, enhances policy effectiveness, forming a spiral upward evolutionary model. Currently, China has transitioned from the policy-driven 1.0 phase to the dual-wheel drive of policy and market in the 2.0 phase. Future efforts should focus on addressing deep-seated issues such as innovation chain breakpoints, shortcomings in factor markets, and weak standards systems. By integrating 'institutional innovation + technological innovation + ecological innovation,' the goal is to achieve a strategic leap from substitution to leadership in the semiconductor materials industry.

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