



Current Status and Manufacturing Potential of Semiconductor Chips Across Countries Worldwide

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ABSTRACT: Semiconductor manufacturing underpins digital economies, artificial intelligence, telecommunications, automotive systems and national technological security. This review examines the global semiconductor value chain, compares the strengths and constraints of major producing economies, and evaluates technological and industrial prospects for 2026–2035. It highlights advanced logic, memory, chiplets, compound semiconductors, supply-chain diversification and opportunities for Vietnam. The analysis distinguishes current industrial capabilities from future policy targets and emphasizes the importance of human resources, infrastructure and international cooperation.

KEYWORDS: semiconductor chips; integrated circuits; CMOS; manufacturing; supply chains; advanced packaging; artificial intelligence.

1. INTRODUCTION

Semiconductor integrated circuits (ICs) underpin computing, telecommunications, artificial intelligence (AI), industrial automation, transportation and healthcare. Since the transistor and the first ICs, advances in lithography, materials and device architecture have enabled the integration of billions of transistors. Yet production now relies on a geographically distributed value chain spanning design, electronic design automation (EDA), materials, equipment, wafer fabrication, assembly, packaging and testing. The United States is strong in design and equipment; Taiwan in advanced contract fabrication; South Korea in memory; Japan and Europe in materials and specialized equipment; and China in large-scale manufacturing. Such specialization creates efficiencies but also exposes firms to trade restrictions, geopolitical disruptions and bottlenecks. This review compares national capabilities, constraints and prospects through 2035, with particular attention to Vietnam (Chen, 2022; Li et al., 2020; Moore, 1998; Moktadir & Ren, 2024; Jeong, 2026).

2. STRUCTURE AND CHARACTERISTICS OF THE SEMICONDUCTOR MANUFACTURING INDUSTRY

2.1. Main stages of the chip production chain

The semiconductor production chain comprises IC architecture and verification, EDA and intellectual property, ultrapure substrates and chemicals, deposition and lithography equipment, front-end wafer processing, and back-end assembly, packaging and testing. Competitive advantage can be located at any of these stages. The United States and parts of Asia dominate IC design; Japan, Germany and the United States supply key materials; the Netherlands, Japan and the United States produce critical equipment; Taiwan and South Korea are central to advanced fabrication; and Southeast Asia participates strongly in assembly and test. Accordingly, national manufacturing capability cannot be reduced to wafer-fab ownership alone (Lau, 2021; Li et al., 2020).

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Fig.1. Semiconductor silicon wafer undergoing probe testing during chip manufacturing. Source: iStock/Getty Images, image ID 887333134 (genkur, 2017).

The semiconductor chip manufacturing process consists of multiple stages, each requiring different levels of technology, capital investment, and human resources.

Table 1. Main Stages of the Semiconductor Chip Manufacturing Process

Stage	Main Activities	Representative Countries/Regions
IC Design	Logic design, chip architecture, verification, and optimization	United States, Taiwan, South Korea, China
EDA Software and IP	Design, simulation, verification tools, and intellectual property cores	United States, Europe
Semiconductor Materials	Silicon wafers, ultrapure gases, chemicals, and photoresist materials	Japan, Germany, United States, South Korea
Manufacturing Equipment	Lithography, deposition, plasma etching, and metrology	Netherlands, United States, Japan
Wafer Fabrication	Fabrication of transistors and interconnect layers on semiconductor wafers	Taiwan, South Korea, China, United States
Packaging and Testing	Chip dicing, interconnection, packaging, and quality testing	Taiwan, China, Malaysia, Vietnam
Product Integration	Integration of semiconductor chips into electronic devices and systems	United States, China, South Korea, Japan

2.2. Classification of semiconductor process technologies

Process generations are commonly identified by nominal nodes such as 28, 14, 7, 5, 3 and 2 nm, although these labels no longer represent one unique transistor dimension. Advanced logic combines EUV lithography, FinFET or gate-all-around (GAA) architectures, precision metrology and stringent defect control. Meanwhile, mature nodes remain indispensable for microcontrollers, sensors, power management, automotive electronics and industrial control. Technology leadership therefore requires evaluating

product mix, yield, cost and supply-chain capabilities rather than the smallest advertised node (Chen, 2022; Mu et al., 2023; Dennard et al., 1974; Waldrop, 2016).

3. CURRENT STATUS OF SEMICONDUCTOR MANUFACTURING WORLDWIDE

3.1. Scale and growth trends of the global semiconductor market

The original report cites global semiconductor sales of approximately US\$630.5 billion in 2024 and US\$791.7 billion in 2025, equivalent to 25.6% growth, based on the Semiconductor Industry Association's February 2026 release. These are market-sales figures rather than wafer-fabrication revenues. AI accelerators, high-bandwidth memory (HBM) and data-center infrastructure are important demand drivers, although consumer and industrial segments remain cyclical. Forecasts for 2026–2035 should consequently distinguish demand growth from physical production capacity (Semiconductor Industry Association [SIA], 2026).

3.2. United States: A center for semiconductor design and technology development

The United States occupies a strategic position in processor architectures, AI-chip design, EDA and semiconductor manufacturing equipment. NVIDIA, AMD, Qualcomm and Broadcom are prominent fabless suppliers, whereas Intel and Texas Instruments combine design with manufacturing capabilities. Applied Materials, Lam Research and KLA provide crucial process and inspection tools. Industrial incentives and investments by domestic and overseas manufacturers aim to rebuild fabrication capacity. High construction costs, specialized workforce requirements and dependence on international inputs remain significant constraints. Its greatest opportunities lie in AI hardware, advanced logic, equipment and next-generation transistor research. (Hennessy & Patterson, 2019; Jouppi et al., 2017).

3.3. Taiwan: The global hub of advanced foundry manufacturing

Taiwan is central to the foundry model, with TSMC supplying advanced logic manufacturing to global computing and communications firms (Liu, 2021). Its advantages include manufacturing scale, process integration, yield management and sophisticated packaging. UMC, ASE and numerous suppliers support the wider ecosystem (Tung, 2001; Wu et al., 2006). Continued development of 2-nm-class processes, chiplets and CoWoS-type advanced packaging may reinforce Taiwan's position. However, geographic concentration exposes the industry to water and electricity constraints, natural disasters and geopolitical risks. Statements about 2-nm revenue recognition should be checked against the relevant dated company disclosures (On the Tailor-Made Water Governance Mechanism, 2024).

3.4. South Korea: A leader in memory and integration technologies

South Korea has substantial capacity in DRAM, NAND flash and advanced integration. Samsung Electronics participates in memory, logic design and foundry services, while SK hynix is particularly strong in memory technologies. AI computing has intensified demand for HBM paired with accelerator chips. Future growth is linked to HBM, advanced DRAM, NAND, GAA logic and memory–processor integration. Exposure to volatile memory prices, export controls and global equipment supply remains an important risk. (Kim, D., & Kim, J. Y. (2022).

3.5. China: Expanding manufacturing capacity and technological self-reliance

China combines a vast electronics market with expanding IC design, wafer manufacturing, packaging and test capacity. Firms such as SMIC, Hua Hong and YMTC illustrate the breadth of its industrial base. Policies emphasize domestic substitution in equipment, materials, design tools and critical process steps. Restrictions on access to advanced lithography and selected technologies complicate leading-edge expansion, while mature-node capacity, power devices, controllers and specialized chips offer near-term opportunities. The pace of self-reliance will depend on technical progress across the complete supply chain. (Jeong, 2026; Moktadir & Ren, 2024).

3.6. Japan: Strengths in materials and manufacturing equipment

Although Japan's position in leading-edge logic manufacturing has changed since the 1980s, it remains influential in silicon wafers, photoresists, ultrapure chemicals, process tools, memory and industrial electronics. Tokyo Electron, Shin-Etsu, SUMCO, Renesas and Kioxia represent complementary capabilities. Rapidus and international partnerships signal renewed interest in advanced logic. Japan is also well positioned in SiC and GaN power devices, sensors and precision manufacturing (Armstrong, 2025).

3.7. Europe: Leadership in lithography and industrial semiconductors

Europe has strategic strengths in lithography equipment, power semiconductors, automotive ICs, sensors and industrial controllers. The Netherlands hosts ASML, a crucial supplier of EUV lithography systems, while companies including Infineon, STMicroelectronics and NXP contribute specialized devices. European initiatives seek to expand fabrication, research and supply

resilience. The region's comparative advantages are particularly pronounced in industrial reliability, energy conversion, SiC/GaN devices and manufacturing equipment. (Waldrop, 2016).

3.8. Singapore and Malaysia: Manufacturing and packaging hubs in Southeast Asia

Singapore supports wafer fabrication, specialized manufacturing and semiconductor research through strong infrastructure and skilled labor. Malaysia, especially Penang and Kulim, has established significant assembly, packaging, testing and supporting-equipment ecosystems. Advanced packaging, three-dimensional integration and chiplets could enable both countries to capture greater value than conventional assembly alone. Singapore may expand specialty production, while Malaysia can build on advanced test and packaging expertise (Lau, 2021; Zhang et al., 2022).

3.9. India: An emerging market with substantial development potential

India is developing a semiconductor ecosystem through design centers, investment programs, packaging projects and workforce initiatives. Its strengths include software, engineering talent and a large domestic electronics market. Large-scale wafer fabrication nevertheless requires sustained capital, reliable utilities, logistics and specialized material supply. Combining international partnerships with IC design, assembly, testing and selected mature-node manufacturing offers a plausible staged development strategy (Ministry of Electronics and Information Technology, 2025, 2026).

3.10. Vietnam: Opportunities for deeper participation in the semiconductor value chain

Vietnam has opportunities arising from its electronics industry, technical workforce and the diversification of Asian manufacturing networks. IC design, engineering services, packaging and testing already provide entry points, supported by investments from international companies including Intel and Amkor. Decision No. 1018/QĐ-TTg, issued on 21 September 2024, sets policy targets for 2030, 2040 and 2050. These are targets, not achieved outcomes. By 2030, the strategy envisages at least 100 chip-design enterprises, one fabrication facility and ten packaging/testing facilities; by 2050, the respective targets rise to at least 300, three and twenty. Sustainable progress requires stronger training, research infrastructure, industrial collaboration and specialization in sensors, microcontrollers, IoT and power electronics (Prime Minister of Vietnam, 2024).

4. COMPARISON OF SEMICONDUCTOR MANUFACTURING CAPABILITIES AND POTENTIAL ACROSS COUNTRIES

A qualitative comparison reveals distinct, complementary strengths. The United States leads in design, EDA and manufacturing equipment; Taiwan in advanced foundry services; South Korea in memory and HBM; China in scale and mature-node expansion; Japan in materials and equipment; and Europe in EUV lithography and industrial power devices. Singapore is strong in specialty wafer manufacturing, Malaysia in packaging and test, India in design talent and emerging investment, and Vietnam in electronics-related engineering and back-end expansion. During 2026–2035, competitive potential will depend on technological depth, human capital, supply reliability and the ability to capture higher-value activities. This is a qualitative assessment rather than a statistical ranking. (Jeong, 2026; Ramirez & Le, 2025).

5. DETERMINANTS OF SEMICONDUCTOR INDUSTRY DEVELOPMENT POTENTIAL

5.1. Research and technological development capacity

Research and development connects universities, national laboratories and manufacturers in transistor design, process control, lithography, dielectric materials and three-dimensional integration. Sustained investment in device physics and materials research is especially important as scaling becomes more difficult (Chen, 2022; Moutanabbir & Gösele, 2010).

5.2. Highly skilled human resources

The sector requires specialists in semiconductor physics, chemistry, materials science, electrical engineering, software, metrology and quality assurance. Education should integrate theoretical foundations, simulation, cleanroom practice, characterization and industry projects. Workforce quality is more decisive than graduate numbers alone.

5.3. Capital investment and infrastructure

Advanced fabs may require investments of many billions of dollars together with cleanrooms, reliable electricity, ultrapure water, industrial gases and chemical treatment. The scale and operating costs make a staged national strategy more realistic than immediate self-sufficiency across every process segment.

5.4. Industrial policy and international cooperation

Effective industrial policy combines investment incentives, intellectual-property protection, training, research facilities and commercial partnerships. International cooperation remains essential because advanced semiconductor production depends on

highly specialized cross-border suppliers. Policy should be evaluated against actual industrial capabilities and long-term market demand. (Moktadir & Ren, 2024; Ramirez & Le, 2025).

6. TECHNOLOGY TRENDS AND DEVELOPMENT PROSPECTS, 2026–2035

6.1. Development of sub-3-nm manufacturing technologies

The progression toward 2-nm-class and later processes involves GAA nanosheets, advanced EUV patterning, backside power delivery and increasingly sophisticated process control. Benefits in density and energy efficiency must be balanced against quantum effects, leakage, variability, heat dissipation and sharply rising costs. New device architectures and materials will complement dimensional scaling (Chen, 2022; Mu et al., 2023). (Dennard et al., 1974; Waldrop, 2016).

6.2. AI processors and high-performance memory

AI accelerators, GPUs and application-specific integrated circuits require high computational throughput and fast memory access. HBM and advanced interconnects are increasingly critical to system-level performance. Energy efficiency, bandwidth, latency and scalability will be as important as peak computational speed. (Jouppi et al., 2017; Hennessy & Patterson, 2019).

6.3. Advanced packaging and chiplet integration

Chiplet architectures integrate smaller dies of different functions and process generations within one package. This approach can improve design flexibility and yield while enabling heterogeneous systems, but introduces interconnect, thermal, test and reliability challenges. Hybrid bonding and 2.5D/3D integration create major opportunities for packaging-oriented economies (Li et al., 2020; Lau, 2021; Zhang et al., 2022; Mahajan et al., 2026). (Das Sharma & Mahajan, 2024; Rafiee & Saini, 2026).

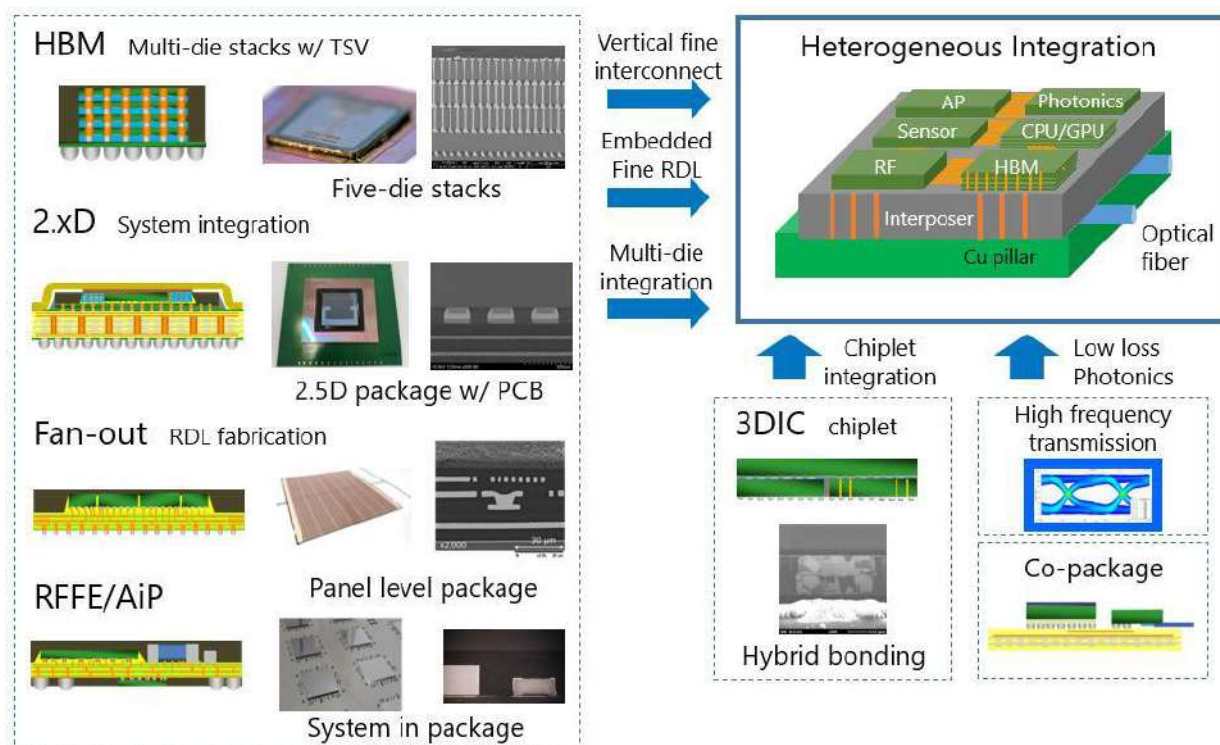


Fig.2. Next-generation semiconductor packaging technologies, including HBM, 2.5D/3D integration, fan-out packaging, chiplets, and heterogeneous integration. Source: Resonac Corporation.

6.4. Next-generation semiconductor materials

Silicon remains the principal IC platform, while silicon carbide and gallium nitride serve high-power and high-frequency applications; gallium arsenide remains important in optoelectronics and selected RF devices. Two-dimensional materials such as graphene and transition-metal dichalcogenides, along with nanoribbons, offer new approaches to controlling electronic properties through geometry, strain, doping and interfaces. Density functional theory (DFT) can screen electronic structure, optical response and material stability, but device-level feasibility also requires experimental evidence of reproducibility, contacts, reliability and CMOS compatibility (Moutanabbir & Gösele, 2010; Chen, 2022). (Novoselov et al., 2004; Radisavljevic et al., 2011; Schwierz, 2010; Akinwande et al., 2019).

6.5. Diversification of semiconductor supply chains

Geopolitical uncertainty and concentrated production are motivating geographic diversification of design, fabrication and back-end facilities. This creates opportunities for Southeast and South Asia, although a competitive ecosystem requires long-term investment in suppliers, talent and institutions. Diversification improves resilience only when new sites develop reliable capabilities and cross-border connections. (Moktadir & Ren, 2024; Ramirez & Le, 2025).

7. OPPORTUNITIES AND DEVELOPMENT DIRECTIONS FOR VIETNAM'S SEMICONDUCTOR INDUSTRY

Vietnam should prioritize realistic entry points rather than immediately competing in the most capital-intensive leading-edge nodes. IC design, specialized sensors, industrial controllers, IoT devices, power electronics, packaging and testing can support a growing technical workforce and supplier base (Prime Minister of Vietnam, 2024a). Over time, investment in materials research, device simulation, prototyping and industrial research centers could improve domestic technological capacity. Interdisciplinary teams should combine semiconductor physics, DFT materials calculations, TCAD device simulation and quantum transport methods (Kim et al., 2026; Sivakumar et al., 2026). University laboratories can progress from design and measurement to prototyping, with training closely linked to industrial requirements. Long-term outcomes will depend on practical engineering competence and sustained international collaboration (Prime Minister of Vietnam, 2024b).

8. CHALLENGES FACING THE GLOBAL SEMICONDUCTOR MANUFACTURING INDUSTRY

The global industry faces five interrelated challenges: rising research and fabrication costs; physical limitations associated with leakage, variability and heat; concentration of specialized equipment and materials suppliers; shortages of highly trained workers; and the environmental burden of electricity, water and chemical consumption. Packaging adds further concerns about thermal management, mechanical stress and testability. Long-term resilience therefore requires a balance among technical performance, economic viability, diversified supply and environmental responsibility (Lau, 2021; Mahajan et al., 2026; Ramirez & Le, 2025).

9. CONCLUSIONS

Semiconductor manufacturing is a strategic global industry structured around deep specialization. The United States, Taiwan, South Korea, China, Japan and Europe occupy different but interconnected positions, while India and Southeast Asian economies can expand through design, specialty manufacturing, packaging and test. AI computing, advanced logic, HBM, chiplets and emerging materials are likely to reshape competition through 2035, but progress will remain constrained by capital, physical limits, skilled labor and geopolitical risks. For Vietnam, combining workforce development, research capability, targeted foreign investment and domestic supporting industries offers a practical pathway toward higher-value participation in the semiconductor ecosystem.

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