

**MEMS INDUSTRY AND ITS RELEVANCE TO MALAYSIA**  
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**INTRODUCTION**

The semiconductor industry has evolved from early devices such as the Schottky diode into one of the most sophisticated and strategically significant global ecosystems. What began as a niche field of electronic components has expanded into a vast, interconnected value chain encompassing chip design, wafer fabrication, assembly and

packaging, testing, materials, specialty chemicals, precision equipment, logistics, and advanced system integration (fig. 1). This ecosystem now forms the backbone of modern technological progress, enabling breakthroughs in artificial intelligence, autonomous and electric vehicles, the Internet of Things, medical diagnostics, aerospace systems, and next-generation communications (fig. 2).

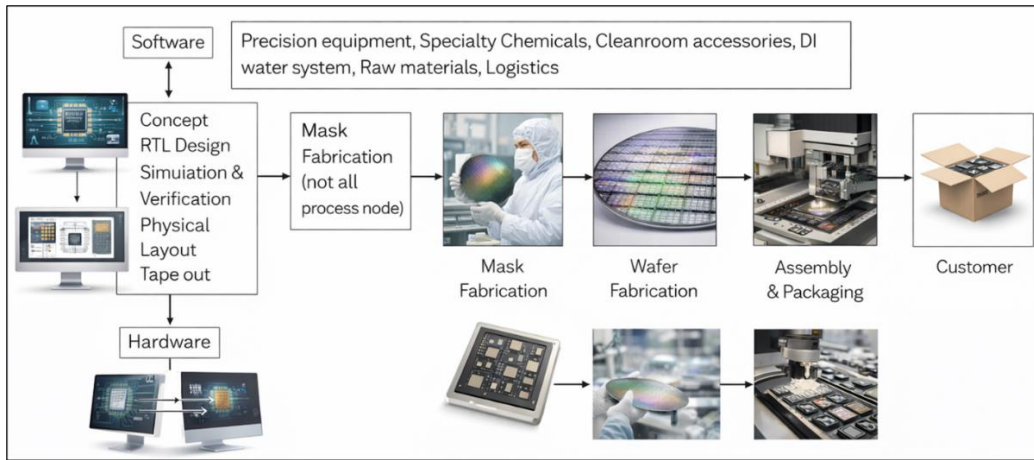


Figure 1. Shows Semiconductor Flow and the Ecosystem

The COVID-19 pandemic exposed the fragility of global semiconductor supply chains and highlighted the world's dependence on a small number of manufacturing hubs. This disruption transformed semiconductors from a purely commercial sector into a strategic national priority. Governments worldwide are now investing aggressively to strengthen domestic capabilities, recognizing that semiconductor capacity underpins national security, economic resilience, and technological

sovereignty. As a result, semiconductor policy has become a defining element of modern industrial strategy, reshaping alliances and accelerating innovation cycles.

Within this global landscape, Malaysia has emerged as a critical player—particularly in assembly, packaging, and testing (OSAT). The country hosts a dense concentration of multinational semiconductor firms and maintains one of the strongest electrical and electronics (E&E) export portfolios in the

region. Malaysia's established infrastructure, skilled workforce, and deep OSAT expertise

position it as an indispensable link in the global value chain.

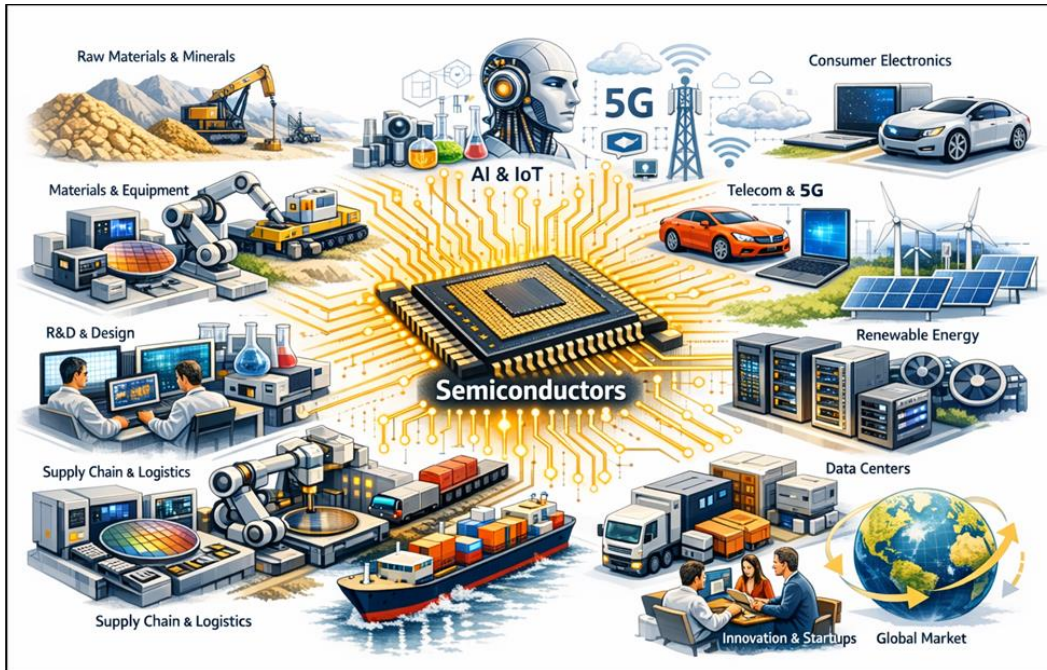


Figure 2. Modern world semiconductor impact

At the same time, the semiconductor industry itself is undergoing a structural shift. For decades, progress was defined almost exclusively by silicon CMOS scaling. Today, however, the industry is diversifying into multiple specialized technology frontiers—including Si-Ge, III-V compounds, GaN-on-Si, SiC, and MEMS—each optimized for different performance, power, and application requirements. This transition opens new strategic pathways for countries like Malaysia to move upstream into higher-value manufacturing segments without the prohibitive capital investment required for leading-edge CMOS fabs. Among these emerging frontiers, MEMS stands out as a particularly compelling opportunity, offering strong market demand, broad application relevance, and a far more accessible technological and economic entry point.

## SEMICONDUCTOR FRONTIER LANDSCAPE

The semiconductor landscape is defined by several critical technology frontiers, each serving distinct performance and market needs (Table 1), and each differentiated by its capital intensity, manufacturing complexity, and ecosystem depth (Table 2). Si CMOS ICs remain the backbone of global computing, powering logic and memory at ever-advancing nodes that demand the highest capex, the densest process integration, and the most mature global ecosystem spanning EDA, IP, materials, and advanced fabs. Si-Ge technologies extend silicon into high-frequency domains with moderate capex and process complexity, enabling RF, high-speed analog, and next-generation 5G/6G communications

while leveraging existing CMOS infrastructure. MEMS platforms, by contrast, rely on specialized micro-machining and heterogeneous integration, requiring lower capex but deep ecosystem coordination across materials, packaging, calibration, and application-specific design to deliver sensors, actuators, and micro-structures for mobility, healthcare, industrial automation, and IoT. In parallel, III–V compound semiconductors such as GaAs and InP dominate photonics, lasers, and ultra-high-frequency RF, supported by niche but highly specialized fabs with unique epitaxy, wafering, and device-physics requirements. Power electronics is being reshaped by GaN-on-Si,

which offers fast switching and high efficiency with moderate capex and growing ecosystem maturity for consumer power, data centers, and renewables, while SiC stands at the high-capex, high-complexity end of the power spectrum, indispensable for high-voltage, high-temperature environments such as electric vehicles and industrial power systems. Together, these frontiers form a diversified semiconductor ecosystem that spans computation, communication, sensing, photonics, and power — each with distinct investment profiles and ecosystem demands that shape national strategy and industrial competitiveness.

Table 1: Comparative Analysis by Applications

SEMICONDUCTOR TECHNOLOGY FRONTIERS				
Frontier	Key Applications	Market Growth	Market Grow	Malaysia Fit
Si CMOS	CPUs, GPUs, DRAM	Very high ↑↑↑	Very low ↑↑	Very low
Si-Ge	RF front-end, 5G	High ↑↑	High ↑↑	Moderate
MEMS	Sensors, IoT, Automotive	High ↑↑	High ↑↑	Very high
III-V	Photonics, lasers	High ↑↑	High ↑↑	Low-moderate
GaN-Si	Power, chargers	High ↑↑	High ↑↑	Moderate
GaN-Si	Power, chargers	High ↑↑	High ↑↑	Moderate
SiC	EVs, industrial power	Very high ↑↑↑	Very high ↑↑↑	Moderate
SiC	EVs, industrial power	Very high ↑↑↑	Very high ↑↑↑	Moderate (high capex)

Table 2: Comparative Analysis by Capex, Complexity, and Ecosystem Needs

SEMICONDUCTOR TECHNOLOGY FRONTIERS				
Frontier	Fab Capex	Development Cost	Equipment Complexity	Talent Requirement
Si CMOS	USD10–20B	USD300–500M	Extreme (EUV)	Very high
Si-Ge	USD1–3B	USD50–100M	High	High
MEMS	USD200–500M	USD5–20M	High	High
III-V	USD500M–1B	USD50–150M	Moderate	Moderate
GaN-Si	USD500M–1B	USD50–150M	High	High
GaN-Si	USD500M–1B	USD50–100M	High	High
SiC	USD1–2B	US100–200M	High	High

### SEMICONDUCTOR ECOSYSTEM GAPS

A complete semiconductor ecosystem spans multiple layers: materials, equipment, front-end wafer fabrication, design, advanced packaging, testing, and system-level integration. Only a handful of countries possess all layer’s end-to-end. Many emerging semiconductor economies—such as Malaysia, the Philippines, and Vietnam—have built strong positions in backend operations, particularly in assembly, packaging, and testing. Among these, Malaysia has one of the most established OSAT footprints, while the Philippines and Vietnam have rapidly expanded their backend capabilities as part of the global supply chain.

However, despite these strengths, backend maturity alone does not constitute a full semiconductor ecosystem, and several

structural gaps continue to limit upward movement into higher-value segments.

The most significant gap across many emerging economies is the absence of front-end wafer fabrication, especially at advanced process nodes. These countries often lack the high-purity materials supply chain, ultra-cleanroom infrastructure, and specialized engineering talent required for nanometer-scale manufacturing. Without these elements, they remain dependent on foreign fabs for front-end production, limiting their ability to capture design-driven or device-level value.

A second major gap is the limited domestic capability in semiconductor equipment manufacturing. Global leaders such as the United States, Japan, the Netherlands, and South Korea dominate the production of lithography systems, deposition tools, etching equipment, and metrology instruments. In contrast, many emerging

economies maintain small and fragmented equipment ecosystems, relying heavily on imported high-value tools. This dependency increases operational costs and makes it more challenging to attract advanced fabs that require a robust local equipment and maintenance infrastructure.

Another structural challenge lies in the talent pipeline. While many countries have strong bases of technicians and engineers for backend operations, they often lack sufficient numbers of specialists in semiconductor physics, device engineering, materials science, and advanced process integration. Competing nations have invested heavily in long-term talent development through university-industry partnerships, specialized research institutes, and targeted incentives to attract global experts. Without similar

investments, emerging economies struggle to support front-end expansion and advanced R&D activities.

Finally, the innovation ecosystem in many developing semiconductor nations remains underdeveloped. Limited semiconductor-focused R&D centers, weak commercialization pathways, and insufficient venture capital participation in deep-tech sectors hinder the growth of local companies. As a result, firms often struggle to scale beyond contract manufacturing into design, IP creation, and high-value technology development. Without a stronger innovation engine, these countries risk remaining manufacturing destinations rather than integrated semiconductor hubs capable of driving their own technological breakthroughs.

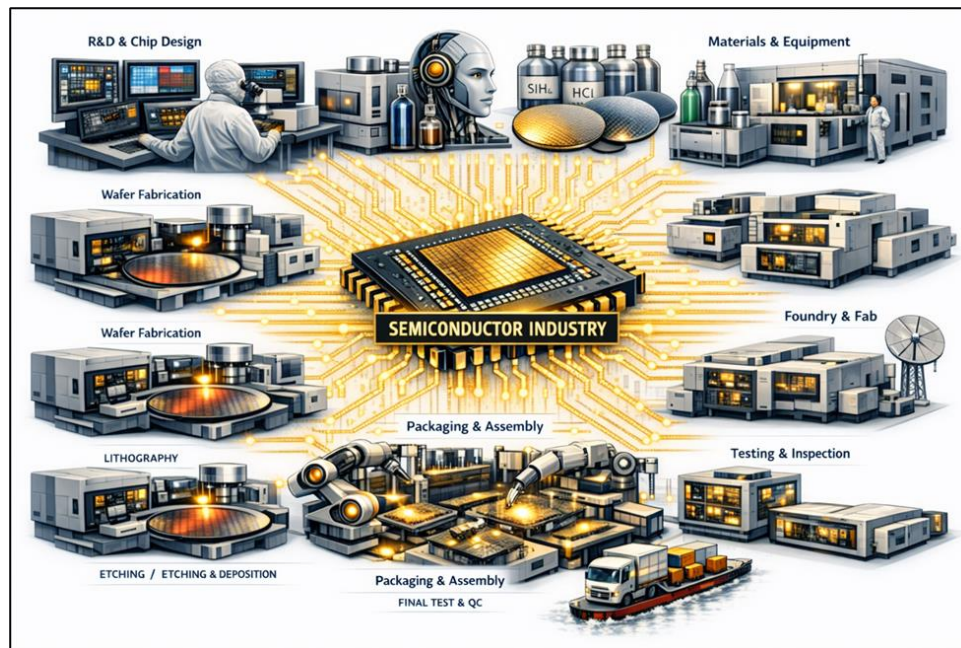


Figure 3. Semiconductor Ecosystem Landscape

## COMPETING COUNTRIES

Countries that entered the semiconductor sector early continue to dominate and benefit from decades of accumulated expertise,

infrastructure, and investment. The United States, Taiwan, South Korea, and Singapore remain global leaders with mature, full-stack ecosystems spanning design, front-end fabrication, equipment manufacturing, and

advanced packaging. Malaysia, while not an early entrant, has built one of the world’s most established backend manufacturing clusters—particularly in assembly, packaging, and testing—and has recently announced national initiatives to expand into a more complete semiconductor ecosystem. This gives Malaysia a strong foundation, but it also places the country in direct competition with other emerging hubs.

Nations such as the Philippines and Vietnam are rapidly strengthening their positions in the global supply chain, especially in large-scale packaging and assembly. Their growing OSAT footprints add competitive pressure in the backend segment, where cost efficiency, labor availability, and supply-chain integration play decisive roles.

At the same time, two major economic powers—China and India—have launched ambitious national strategies aimed at

achieving semiconductor self-reliance. Both are investing billions of dollars to build domestic capabilities across design, manufacturing, and advanced packaging. China holds a significant head start, with established infrastructure and a rapidly expanding ecosystem, while India, a later entrant, is accelerating its progress through substantial government-backed incentives and large-scale industrial programs.

This evolving landscape intensifies competition on multiple fronts. Countries seeking to move beyond backend operations must contend not only with leading-edge manufacturers such as TSMC and GlobalFoundries, but also with the massive investments being deployed by the United States, China, India, and other nations aiming to capture greater global market share. As a result, the competitive environment is becoming increasingly crowded, capital-intensive, and strategically complex.

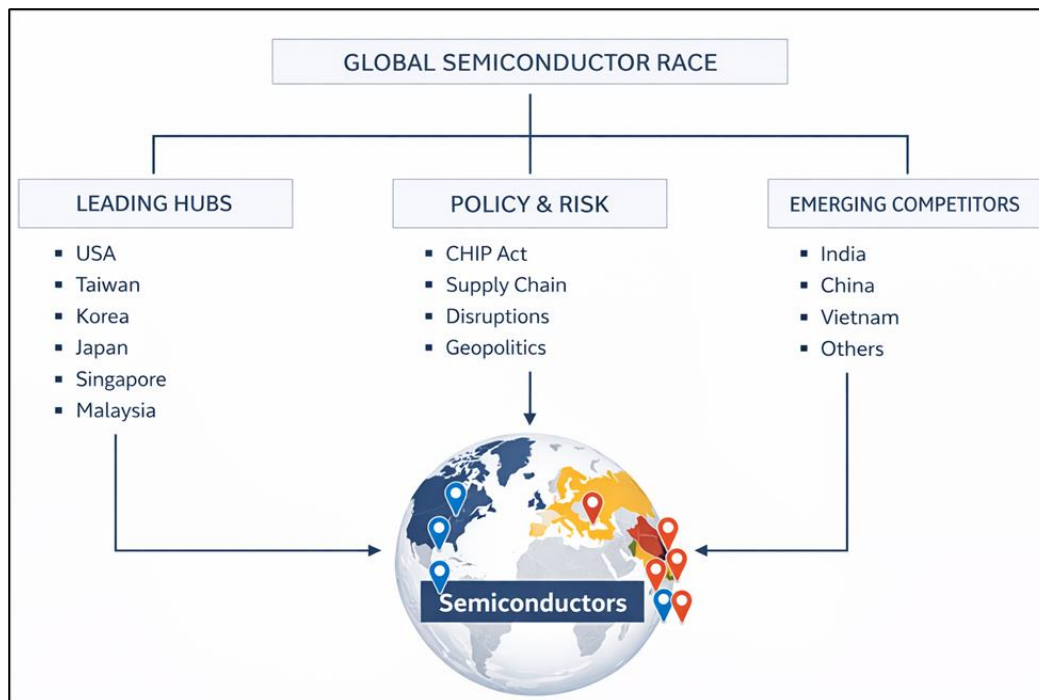


Figure 3. Describing the Countries in Race

## **SEMICONDUCTOR MANUFACTURING MODELS**

As the semiconductor industry matured and capital intensity rose sharply, the traditional fully integrated model evolved into a dual-track architecture defined by Integrated Device Manufacturers (IDMs) on one side and the fabless–foundry–OSAT ecosystem on the other. In the IDM model, companies such as Intel and Samsung Electronics maintain end-to-end control of the value chain—from design and wafer fabrication to assembly, packaging, and testing. This structure enables tight co-optimization of design and process technologies, superior performance tuning, and strong protection of intellectual property. However, it demands exceptionally high capital expenditure, long development cycles, and deep technical integration, making it viable only for a small number of global players.

The fabless model emerged as a response to escalating fabrication costs, allowing companies like AMD and Qualcomm to focus exclusively on architecture, circuit design, and product innovation. Wafer manufacturing is outsourced to pure-play foundries such as TSMC, Samsung Foundry, and GlobalFoundries—firms that specialize in capital-intensive fabrication and operate at massive scale. Downstream, Outsourced

Semiconductor Assembly and Test (OSAT) providers handle packaging, final test, and reliability screening. This distributed model leverages specialization, shared infrastructure, and economies of scale, significantly reducing barriers to entry and accelerating time-to-market.

Malaysia plays a pivotal role in this second model: it is one of the world’s most important OSAT hubs, with deep expertise in advanced packaging, test engineering, and high-volume manufacturing. This makes Malaysia naturally aligned with technologies such as MEMS, where packaging and system-level integration are critical value drivers. Meanwhile, other semiconductor frontiers map differently across these business models: Si-Ge and III–V devices often remain within IDM-centric ecosystems due to specialized processes; GaN-on-Si and SiC are typically produced in specialty foundries; and MEMS spans all models, from IDM-style sensor manufacturers to pure-play MEMS foundries and fabless design houses.

Together, the coexistence of IDM and fabless–foundry–OSAT models has created a highly optimized global supply chain—balancing vertical integration with horizontal specialization—and enabling rapid innovation across diverse semiconductor frontiers.

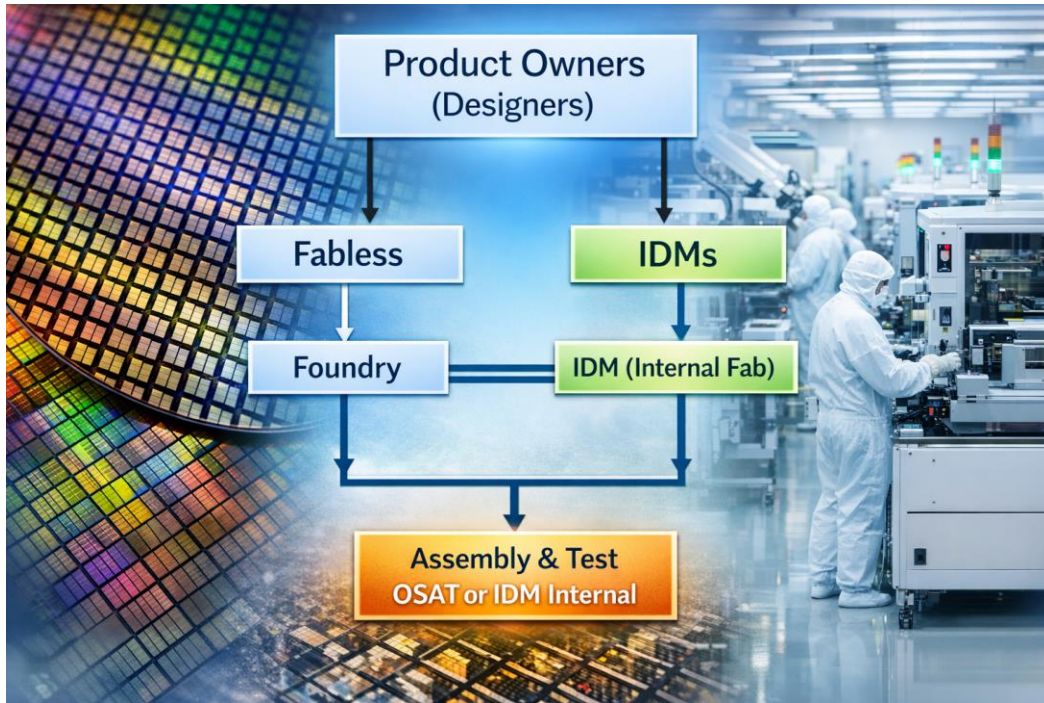


Figure 4. Semiconductor Industry Model

## ECONOMIC REALITIES OF HIGH-END IC DESIGN & MANUFACTURING

The semiconductor industry has advanced to process nodes approaching 2 nm and below, with only a handful of global leaders operating at the 3 nm frontier. Many companies have chosen not to pursue further miniaturization because the financial, technical, and talent barriers have become extraordinarily high. Some major foundries, for example, halted at 12 nm and shifted toward more sustainable specialty technologies.

Building and operating a leading-edge fabrication facility is now a multibillion-dollar undertaking. Designing chips for advanced nodes requires hundreds of millions of dollars, access to EUV-class equipment, and a deep pool of highly

seasoned engineers—talent that takes decades to cultivate. Even globally, universities cannot realistically train students on cutting-edge nodes; most academic programs still rely on 180 nm, 90 nm, or 40 nm technologies because access to sub-40 nm tools is prohibitively expensive.

To illustrate the scale:

### Estimated Cost & Talent Requirements

- Building a leading-edge fab: US \$10–20 billion
- Developing a new process node: US \$300–500 million
- Designing a commercial-grade chip at 40 nm:
  - Cost: US \$20–50 million
  - Engineering team: ~150–300 engineers across RTL, verification, physical design,

- DFT, firmware, and validation
  - Timeline: 18–30 months from architecture to tape-out
- Designing at 28 nm or 16 nm:
  - Cost: US \$80–200 million
  - Engineering team: 400–800 engineers
  - Timeline: 24–36 months
- Designing below 10 nm:
  - Cost: US \$300–600 million
  - Engineering team: 1,000+ engineers
  - Timeline: 3–5 years
- Equipment complexity: Extreme (EUV lithography, advanced metrology, multi-patterning)
- Talent ecosystem: Dense, specialized, globally competitive

Given these realities, any country aspiring to build high-end IC design capability must take a measured, evidence-based approach. Committing prematurely to expensive proprietary technologies without a mature ecosystem often leads to high cost with limited long-term capability.

A more sustainable strategy is to invest heavily in talent development—potentially hundreds of millions of dollars directed toward university programs, labs, and long-term training pipelines. Students can be trained using open, accessible architectures and legacy nodes (180 nm–40 nm), building strong fundamentals before progressing into advanced-node work through industry placements and collaborations with companies operating at the cutting edge.

Alternatively, governments may choose to focus on semiconductor frontier technologies—such as MEMS, SiC, GaN, advanced packaging, photonics, or specialty materials—which align more realistically with national capabilities, capital availability, and ecosystem maturity.

This approach builds genuine, long-term national strength rather than relying on symbolic or premature commitments.

### **CHOOSING THE FRONTIERS THAT FITS ECONOMY & ENVIRONMENT**

Governments evaluating semiconductor opportunities must carefully select frontiers that align with national capabilities, economic realities, and long-term talent development. Among the viable alternatives, MEMS stands out as one of the most cost-effective yet high-impact pathways, offering outcomes comparable to other semiconductor domains but at a fraction of the capital and ecosystem burden.

The MEMS industry represents a uniquely strategic frontier for smaller economies. It combines high value-creation potential with the lowest capex requirements across the semiconductor spectrum, making it accessible without the prohibitive financial thresholds associated with leading-edge logic, advanced power devices, or sub-10 nm design. MEMS fabrication also offers one of the fastest commercialization cycles—typically 2 to 4 years—allowing countries to scale industrial capability quickly, attract anchor tenants, and expand downstream supply chains with far lower risk.

Importantly, MEMS manufacturing aligns exceptionally well with the strengths of

countries such as Malaysia, which already possess a world-class OSAT sector, a broad 200 mm wafer processing base, and deep expertise in sensor packaging, module assembly, and reliability testing. This natural compatibility reduces ecosystem friction and enables a rapid transition from assembly-centric participation to full-stack device manufacturing.

With the broadest application footprint of any semiconductor category—spanning consumer electronics, automotive safety, industrial automation, medical diagnostics, environmental monitoring, and defense sensing—MEMS provides diversified market access and resilience against sector-specific volatility. At the same time, MEMS delivers substantial technological and economic value without requiring EUV, advanced-node lithography, or ultra-complex process integration, making it an ideal frontier for national capability building, SME participation, and regional cluster development.

Positioning MEMS as a national priority would allow Malaysia to capture a rapidly expanding global market, strengthen supply chain sovereignty, and establish itself as a leading hub for sensor innovation, advanced packaging, and heterogeneous integration—all of which are foundational to the next decade of digital, automotive, and industrial transformation.

## **GLOBAL MEMS MARKET TREND AND GROWTH DRIVERS**

The global MEMS (Micro - Electro - Mechanical Systems) industry has expanded steadily since its emergence in the early

1980s, evolving from niche scientific curiosity into one of the foundational pillars of modern electronics. Over the past four decades, MEMS sensors have penetrated a wide spectrum of applications—automotive, consumer electronics, industrial automation, medical diagnostics, defense systems, and even aerospace platforms. Each new wave of technological transformation has amplified the relevance of MEMS: first the rise of embedded electronics, then the proliferation of mobile devices, followed by the Internet of Things (IoT), and now the acceleration brought by artificial intelligence. Together, these forces have pushed MEMS from supporting roles into central enablers of intelligent, connected systems.

The automotive sector has historically been the strongest beneficiary of MEMS innovation. From early pressure sensors and accelerometers to today's complex inertial measurement units and LiDAR components, MEMS has been instrumental in improving fuel efficiency, enhancing occupant safety, and enabling advanced driver-assistance systems. Modern vehicles integrate dozens of MEMS devices working in coordination with electronic control units, forming the sensory backbone of the car. This long-standing relationship between MEMS and automotive engineering continues to deepen as electrification and autonomous driving demand even higher levels of precision sensing.

Consumer electronics represent the second major growth engine for MEMS. The smartphone revolution transformed the scale and economics of MEMS manufacturing. A typical high-end mobile phone today incorporates more than 15 MEMS-based components—including microphones, accelerometers, gyroscopes, pressure sensors, magnetometers, and optical MEMS.

The transition to surface-mount MEMS microphones is a striking example: within a decade, they replaced nearly all legacy electret condenser microphones, mirroring the earlier shift in the 1990s when single-point MEMS accelerometers displaced bulky air-bag crash sensors. This cycle of replacement, miniaturization, and performance improvement continues to drive MEMS adoption across wearables, AR/VR devices, and smart home systems.

Beyond automotive and consumer markets, MEMS is now a critical enabler of Industrial IoT, where distributed sensing, predictive maintenance, and real-time monitoring depend on robust, low-power devices. In healthcare, MEMS technologies such as microfluidics and lab-on-chip platforms are reshaping diagnostics, enabling portable, rapid, and cost-effective testing. Defense and aerospace applications rely on MEMS for ruggedized inertial navigation, environmental sensing, and mission-critical instrumentation. These diverse sectors collectively reinforce the resilience and long-term growth trajectory of the MEMS ecosystem.

Market forecasts consistently project strong compound annual growth rates (CAGR), driven by expanding unit volumes, new sensing modalities, and the integration of MEMS into AI-enabled edge systems. When compared with other semiconductor

frontiers, MEMS demonstrates a similar scale of packaging maturity, manufacturing sophistication, and ecosystem depth. The technology's ability to combine mechanical structures with semiconductor processes gives it a unique position—bridging the physical and digital worlds in ways few other technologies can match.

## **MEMS RELEVANCE**

The following tables illustrate how MEMS technology stands shoulder-to-shoulder with other major semiconductor frontiers, reinforcing its strategic relevance across every major market segment. While ICs, Si-Ge, III-V compounds, GaN-Si, and SiC each dominate their respective domains, MEMS uniquely spans them all by enabling the physical-to-digital interface essential for modern systems. Its presence across consumer electronics, automotive platforms, industrial automation, medical instrumentation, and defense technologies demonstrates that MEMS is not a peripheral technology but a parallel pillar of the semiconductor ecosystem. These comparisons highlight how MEMS continues to evolve in capability, packaging maturity, and application breadth—solidifying its role as a critical enabler in the next generation of intelligent, connected devices.

Table 3. MEMS shoulder-to-shoulder with other technologies

Segments / Technology						
	IC Chip	Si-Ge	MEMS Sensor	III-V Compound	GaN-Si	SiC
<b>Consumers</b>	★★★★★ Microcontrollers, SoCs, memory, RF chips	★★★★★ High-speed RF front-ends, Wi-Fi/BT modules	★★★★★ Accelerometers, gyros, microphones, pressure sensors	★★★★★ LEDs, laser diodes for displays	★★★★★ Power adapters, fast chargers	★★★★★ Limited use (premium power devices)
<b>Automotive</b>	★★★★★ ECUs, ADAS processors, infotainment	★★★★★ Radar transceivers, V2X RF, high-speed links	★★★★★ Pressure, inertial, flow, LIDAR MEMS	★★★★★ High-frequency radar, optical comms	★★★★★ On-board chargers, DC-DC comms	★★★★★ Traction inverters, power modules
<b>Industrial</b>	★★★★★ PLCs, controllers, industrial computing	★★★★★ High-speed industrial RF, precision analog	★★★★★ Vibration, pressure, flow, environmental sensors	★★★★★ High-power lasers, RF devices	★★★★★ Motor drives, power supplies	★★★★★ High-temperature, high-voltage power electronics
<b>Medical</b>	★★★★★ Imaging processors, implantable ICs	★★★★★ RF links, front-ends analog	★★★★★ Pressure, flow, accelerometers	★★★★★ Laser diodes for surgical tools	★★★★★ Medium (power supplies for equipment)	★★★★★ High-reliability power devices
<b>Defense</b>	★★★★★ Radar processors, secure ICs	★★★★★ High-frequency RF, secure comms, radar front-ends	★★★★★ Specialized inertial sensors	★★★★★ Radar, EW, IR detectors, high-frequency RF	★★★★★ High-power RF amplifiers	★★★★★ Ruggedized power electronics, high-temperature systems

Table 4. Relevance of MEMS vs Other technologies in AI & IoT Growth

Key Technologies Driving AIoT Growth			
Technology	Role in AI	Role in IoT	Overall Relevance to AIoT Growth
<b>MEMS Sensors</b>	★★★★★ Critical input data (motion, inertial, pressure, LiDAR, audio)	★★★★★ Primary sensing layer for all IoT devices	★★★★★ Primary sensing layer for all IoT devices
<b>IC Chips (CPU/GPU/MCU)</b>	★★★★★ AI compute engines (training + inference)	★★★★★ Edge compute + connectivity	★★★★★ Edge compute + connectivity
<b>Si-Ge (Silicon – Germanium)</b>	★★★★★ High-speed RF, mmWave, and analog front-ends supporting AI communication and sensing	★★★★★ Wi-Fi/BT/5G RF modules, precision RF links for IoT devices	★★★★★ Wi-Fi/BT/5G RF modules, precision RF links for IoT devices
<b>III-V Compounds (GaAs/InP)</b>	★★★★★ Optical sensing, LiDAR, high-speed links	★★★★★ RF front-ends for IoT connectivity	★★★★★ RF front-ends for IoT connectivity
<b>GaN-Si</b>	★★★★★ Power for AI servers, RF amplifiers	★★★★★ RF Power for IoT gateways, chargers	★★★★★ Important, but not universal across all AI/IoT devices
<b>SiC</b>	★★★★★ High-voltage power for EVs, industry	★★★★★ Power for industrial IoT & EV systems	★★★★★ Supports infrastructure, not core to sensing or intelligence

Table 4. Relevance of MEMS Industry in the Rapidly Growing AI and IoT World

Role of MEMS Sensors in AI and IoT			
Category	Role of MEMS Sensors	Impact on AI	Impact on IoT
Data Generation	Provides motion, pressure, inertial, acoustic, and environmental sensing	Supplies high-fidelity real-world inputs for AI perception, prediction, and decision logic	Forms the foundational sensing layer that enables IoT devices to monitor physical conditions
Automotive	LIDAR MEMS, inertial units, pressure, and safety-critical sensors	Enables ADAS, autonomous functions, and decision logic	Powers V2X, telematics, and connected-vehicle event systems
Automotive	LIDAR MEMS, inertial units, pressure, and safety-critical sensors	Enables ADAS, autonomous functions, and decision logic	Powers V2X, telematics, and connected-vehicle event systems
Industrial	Vibration, flow, and environmental MEMS for harsh environments	Supports predictive maintenance, robotics, and remote industrial automation	Forms the sensor backbone of smart factories and remote industrial automation
Medical	Pressure sensors, biosensors, micro-pumps, and microfluidic MEMS	Enhances diagnostics, imaging AI, and continuous patient monitoring	Forms the sensor backbone of smart factories, and remote industrial monitoring
Consumer	Microphones, motion sensors, pressure sensors for compact devices	Powers voice assistants, imaging AI, and contextual intelligence	Drives wearables, smart-home devices, and remote industrial
Defense	High-precision inertial MEMS and ruggedized sensing	Supplies targeting, surveillance, autonomous defense systems	Enables secure sensor networks and battlefield IoT infrastructure

Table 4. Relevance in Capital Investment vs Output Potential

Technology Investment Comparison						
Comparative Analysis of Semiconductor Technology Investments						
Technology	Minimum CaPEX	Revenue Potential	Future Growth	Employment Creation	Strategic Value	Strategic Value
IC (CMOS)	Very High (USD 3-7B)	Very High	Very High	Very High	Very High	Very High
MEMS	Low (USD 150-500M)	High	High	High	High	High
Si-Ge (Silicon-Germanium)	Medium (USD 300-800M)	High	High	High	High	High
III-V (GaAs, InP)	Medium (USD 300-800M)	High	High	High	High	High
GaN (Power + RF)	Medium (USD 500-800M)	Medium	High	High	High	High
SiC	Medium (USD 1-2.5B)	High	High	High	High	Medium

## Strategic Interpretation

IC (CMOS)	MEMS	Si-Ge (Silicon-Germanium)	III-V	GaN-Si	SiC
<p><b>Pros:</b></p> <ul style="list-style-type: none"> <li>• Mature, scalable, cost-efficient</li> </ul> <p><b>Cons:</b></p> <p>Extremely high capital cost, dominated by TSMC, Samsung, and Intel</p> <p><b>Best for:</b></p> <p>Broad electronics consumer and industrial policy</p>	<p><b>Pros:</b></p> <ul style="list-style-type: none"> <li>• Low-cost sensing and actuation</li> </ul> <p><b>Cons:</b></p> <p>Moderate cost; requires RF and epitaxy expertise</p> <p><b>Best for:</b></p> <p>Telecom, connectivity, consumer, and industrial sensing</p>	<p><b>Pros:</b></p> <ul style="list-style-type: none"> <li>• High-speed RF &amp; mmWave; ideal for 5G/6G and mixed-signal integration</li> </ul> <p><b>Cons:</b></p> <p>Moderate cost; requires RF and epitaxy expertise</p> <p><b>Best for:</b></p> <p>Telecom, connectivity, and mixed-signal economies</p>	<p><b>Pros:</b></p> <ul style="list-style-type: none"> <li>• Superior photonics and high-frequency performance</li> </ul> <p><b>Cons:</b></p> <p>Moderate cost; requires RF and epitaxy expertise</p> <p><b>Best for:</b></p> <p>Photonics, satellite, aerospace, and high-end RF</p>	<p><b>Pros:</b></p> <ul style="list-style-type: none"> <li>• High-efficiency RF and mid-power switching</li> </ul> <p><b>Cons:</b></p> <p>Thermal and substrate limitations</p> <p><b>Best for:</b></p> <p>Photonics, satellite, aerospace, and high-end RF</p>	<p><b>Pros:</b></p> <ul style="list-style-type: none"> <li>• High-voltage, high-temperature power capability</li> </ul> <p><b>Cons:</b></p> <p>Expensive materials and processing</p> <p><b>Best for:</b></p> <p>EVs, industrial power, and energy infrastructure</p>

## MEMS MANUFACTURING

MEMS manufacturing is increasingly recognized as a high-value, lower-capex alternative to other frontier segments in the semiconductor industry. With fabrication costs typically ranging between US \$200–500 million, MEMS fabs demand far less capital investment than advanced CMOS or SiC facilities while delivering strong margins across automotive, medical, consumer, and industrial applications. The process relies on proven equipment—deep reactive ion etching (DRIE), wafer bonding, and mature lithography—allowing faster setup and shorter development cycles. This accessibility makes MEMS an attractive entry point for emerging semiconductor economies seeking rapid industrial participation without billion-dollar overheads.

Strategically, MEMS manufacturing aligns well with Malaysia’s OSAT ecosystem, leveraging existing strengths in packaging, testing, and integration. Because MEMS fabs remain profitable even at smaller production

volumes, they offer a sustainable model for regional growth and innovation. In essence, MEMS combines technical sophistication with economic efficiency, providing a pragmatic pathway for nations to build semiconductor capability and advance toward technological self-reliance.

## MALAYSIA AS A STRATEGIC FIT FOR MEMS MANUFACTURING

Malaysia is exceptionally well positioned to become a regional hub for MEMS manufacturing, thanks to a combination of industrial maturity, talent depth, and strategic policy direction. The country already possesses strong foundations in OSAT services, supported by a skilled technician base and a supply chain that has been refined over decades of leadership in the E&E sector. This existing ecosystem reduces barriers to scaling MEMS production, where packaging, testing, and module-level integration are just as critical as wafer fabrication. Government incentives and Malaysia’s long-standing focus on electronics further strengthen the business case, creating an environment where

MEMS investments can achieve rapid traction and sustainable growth.

What makes MEMS particularly aligned with Malaysia's national capabilities is the fit between the technology's scale and the country's investment appetite. MEMS fabs require far lower capital expenditure than advanced CMOS or SiC facilities, yet they deliver high-value products with strong global demand. This creates a realistic pathway for Malaysia to move upstream into wafer-level manufacturing, complementing its OSAT strengths and elevating its position in the semiconductor value chain. With the right incentives and partnerships, Malaysia can attract global MEMS players seeking cost-efficient, high-quality manufacturing locations—transforming the country into a strategic node for next-generation sensing technologies that power AI, IoT, automotive, medical, and industrial systems.

## CONCLUSION

Malaysia's semiconductor ambitions are best served by positioning MEMS as the country's strategic semiconductor frontier, offering the strongest balance of feasibility, investment efficiency, national impact, and

global relevance. Unlike capital-intensive technologies such as advanced CMOS, SiC, or III–V, MEMS provides a realistic and economically sound route for Malaysia to deepen its semiconductor capabilities without the multi-billion-dollar barriers that typically limit upstream expansion. Its alignment with Malaysia's existing strengths—OSAT maturity, a skilled technical workforce, and a robust E&E ecosystem—makes MEMS not only viable but strategically advantageous for long-term industrial development.

By anchoring its next phase of semiconductor growth in MEMS, Malaysia gains a credible and achievable pathway to move upstream into wafer-level manufacturing, strengthening national resilience and elevating its position in global supply chains. At the same time, MEMS lays the groundwork for future diversification: once the ecosystem, talent, and infrastructure are established, Malaysia can selectively expand into SiC, GaN, or III–V technologies as demand and investment appetite evolve. In this way, MEMS becomes both a catalyst and a foundation—an entry point that accelerates capability today while enabling broader semiconductor leadership tomorrow.

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## Acronyms and Abbreviations

- **MEMS** – Microelectromechanical Systems; miniaturized devices integrating mechanical and electrical components on a chip
- **Actuator** – A device that converts electrical energy into physical motion (e.g., movement, vibration, displacement), commonly used in MEMS for sensing and control functions
- **IDM** – Integrated Device Manufacturer; a company that designs, manufactures, and sells semiconductor devices in-house (e.g., own fabs and production lines)
- **OSAT** – Outsourced Semiconductor Assembly and Test; companies that provide packaging and testing services for semiconductor devices
- **IC** – Integrated Circuit; a semiconductor device containing multiple electronic components (transistors, resistors, etc.) on a single chip
- **CMOS** – Complementary Metal-Oxide-Semiconductor; a widely used technology for constructing ICs, known for low power consumption
  - **EUV (Advanced Node)** – Extreme Ultraviolet Lithography; an advanced semiconductor manufacturing technology used in CMOS fabrication for leading-edge process nodes (e.g., 7 nm, 5 nm, 3 nm) enabling extremely fine patterning resolution
- **RF** – Radio Frequency; electromagnetic signals typically in the range of ~3 kHz to 300 GHz, used in wireless communication
- **III–V Compound** – Semiconductor materials formed from elements in Group III and Group V of the periodic table (e.g., GaAs, InP), commonly used for high-speed and optoelectronic applications
  - **GaAs** – Gallium Arsenide; a III–V compound semiconductor used in RF, microwave, and optoelectronic devices
  - **InP** – Indium Phosphide; a III–V compound semiconductor used in high-speed electronics and optical communication systems
- **Si** – Silicon; the most widely used semiconductor material in electronics
- **Ge** – Germanium; a semiconductor material used in high-speed and infrared applications
- **GaN** – Gallium Nitride; a wide bandgap semiconductor used in high-power, high-frequency, and optoelectronic devices
- **SiC** – Silicon Carbide; a wide bandgap semiconductor material used for high-power, high-temperature, and high-efficiency electronic applications
- **EDA** – Electronic Design Automation; software tools used for designing, simulating, and verifying electronic circuits and semiconductor devices

- **IP** – Intellectual Property; legally protected inventions, designs, and proprietary technologies, or reusable design blocks (IP cores) in semiconductor design
- **DRIE** – Deep Reactive Ion Etching; an anisotropic plasma etching process used to create deep, high-aspect-ratio structures in silicon
- **LiDAR** – Light Detection and Ranging; a sensing technology that uses laser pulses to measure distance and generate precise 3D maps
  - **IoT** – Internet of Things; a network of interconnected devices that collect and exchange data via the internet
- **ECU** – Electronic Control Unit; an embedded system in vehicles that controls specific functions such as engine, braking, or infotainment
- **ADAS** – Advanced Driver Assistance Systems; electronic systems that assist drivers with safety features such as lane keeping, collision avoidance, and adaptive cruise control
- **SoC** – System on Chip; an integrated circuit that combines multiple system components (CPU, memory, interfaces) onto a single chip
- **Wi-Fi/BT** – Wireless Fidelity / Bluetooth; wireless communication technologies used for data transmission over short and medium ranges