7th FRAUNHOFER INNOVATION & TECHNOLOGY PLATFORM (FIT)

Microelectronics and Semiconductors

Knowledge Paper

Indo-German cooperation in Microelectronics and Semiconductors

- Sensors
- CMOS Chip Design
- Power Electronics
- Semiconductor Packaging
- MEMS
- Microwave & Terahertz
- Optoelectronics
- System Reliability & Testing
- Skilling

Contents

Foreword

It is with great pleasure that we announce a significant strategic collaboration between Fraunhofer and the EPIC Foundation, focused on strengthening India's Microelectronics, Semiconductor & Electronics ecosystem with a mission to build India as a Product Nation, rooted in Indian IP and brands.

EPIC Foundation believes that the Indian Industry could benefit from Fraunhofer's TRL6++ solutions to move up the value chain to build Indian products, while the Indian Research and Academic Institutions could benefit from Fraunhofer's technologies to build TRL6++ level solutions for the Indian Industry.

EPIC and Fraunhofer jointly organized a high-level Planning Workshop on Indo-German Cooperation in Microelectronics and Semiconductors to develop a Draft Charter and Roadmap for India-Fraunhofer Collaboration in Microelectronics, Semiconductor & Electronics areas.

I strongly urge the India's industry as well as India's academic and research institutions to take this knowledge paper as a starting point to initiate dialogue with Fraunhofer Microelectronics Alliance, Research Fab Microelectronics (FMD) and build upon it to find areas of cooperation and collaboration with Fraunhofer towards building India as a Product Nation to achieve our Prime Minister's vision of Atmanirbhar Bharat.

Dr. Ajai Chowdhry
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Padma Bhushan Recipient
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Distinguished Fellow–NITI Aayog

Aligning technology strengths for charting a strong partnership: Indo-German cooperation in Microelectronics and Semiconductors

Carl Sagan famously said several decades ago" We have arranged civilisation in which most crucial elements profoundly depend on science and technology" In this exciting Techade of fast-paced advancements in Technology and Innovation, tech sovereignty has become the key pillar for any country today to achieve economic progress. Globally, partnerships between countries are today more dependent on technology imperatives and alignment based on complementary strengths to curate mutually rewarding economic value creation. The frontier technology areas such as Artificial Intelligence, Sustainable green technologies, Digital technologies, multidisciplinary Mobility concepts as well as Semiconductors are foundational to modern technology and play a critical role in the global economy, driving innovation across numerous sectors.

Semiconductors are at the core of electronic devices, enabling everything from smartphones and computers to advanced medical equipment and military systems. The semiconductor industry's growth is closely linked to advancements in computing, communication, and other key areas, making it a crucial factor in global competitiveness. This industry is a significant contributor to global GDP, stimulating downstream applications like AI and big data. Countries with advanced semiconductor capabilities often have a competitive edge in developing and manufacturing innovative products, impacting their overall economic standing, while they are also seen as essential for achieving global climate and sustainability goals, enabling technologies for renewable energy and energy efficiency. The ongoing development of new semiconductor technologies, such as those for 5G and AI, will continue to shape the future of technology and its applications.

The geopolitical impact of Semiconductors cannot be underestimated. They are a strategically important commodity, with countries vying for leadership in their design and manufacturing. The global semiconductor value chain is complex and involves various players, making it susceptible to geopolitical risks and competition. Standardization of semiconductor technologies is a key aspect of competition, with nations seeking to establish their standards for chip manufacturing and certification.

As the global technology landscape undergoes rapid shifts, the partnership between India and Germany is assuming new significance—not just geopolitically, but technologically and economically. Against the backdrop of global supply chain disruptions, advances in digital infrastructures, and an urgent focus on resilience and sustainability, Indo-German collaboration stands out as a model for how nations can combine strengths to drive innovation.

Germany brings deep R&D expertise, proven technology transfer models, and advanced engineering to the table, while India offers fertile ground for industrial scaling, thanks to a booming market, a young talent pool, and growing appetite for advanced technologies. On the other hand, India offers an excellent platform for industrial scaling, thanks to its high-growth industry, young talent base, and strong application market.

Against this backdrop, Fraunhofer which is a world leader in applied research, hosting over 75 institutes and creating several path breaking, transformational technologies such as white LEDs and MP3 software, is spearheading a strategic partnership between India and Germany to accelerate technology development and deployment in Microsystems and Semiconductors. As pioneers of the German "Lab to Fab" mode, an effective method for translating scientific findings into industrial value creation in a structured way, Fraunhofer brings multidisciplinary and complete value chain expertise and experience to strengthen India's technology landscape. This proven and highly regarded model of technology and innovation combines applied research, industry-oriented infrastructure, and technology-neutral access, offering a clear path from research to production, especially for SMEs and start-ups.

We are delighted to partner with the Fraunhofer Microelectronics Alliance, Research Fab Microelectronics (FMD) and the EPIC Foundation to develop this Knowledge Paper on Semiconductors. The synergies developed through Germany's engineering temper, precision capabilities, and research excellence combining with India's vibrant market, entrepreneurship spirit and manufacturing capabilities are exciting, and can transform the world. By working together, we can develop technologies and products that not only strengthen both economies but also provide solutions for global challenges.

Ms. Anandi Iyer
Director, Fraunhofer Office India
Member, India and Germany CEO Forum: A G2G Initiative
Member, Vision Group, Government of Karnataka

India Scenario

Introduction

Between January and July 2025, India's semiconductor industry has demonstrated remarkable progress, positioning itself as a key player in the global chip ecosystem. With strategic investments, policy support, and a surge in domestic demand, the sector is undergoing a transformative shift. This report outlines the major developments, policy initiatives, research advancements, and challenges faced by the industry during this period.

Major Infrastructure Developments

India has witnessed several landmark infrastructure projects in the semiconductor domain:

- The launch of the country's first silicon carbide (SiC) semiconductor plant in Odisha by RIR Power Electronics Ltd., with an investment of ₹6.2 billion, targeting electric vehicles and renewable energy sectors.
- Continued progress on the Tata-PSMC fab in Gujarat, with mass production expected by 2026.
- Expansion into third-generation semiconductor technologies, including gallium nitride (GaN), to support high-frequency and power-efficient applications.

Policy and Budgetary Support

The Union Budget 2025 reinforced India's commitment to semiconductor self-reliance:

- Allocation of over ₹1.26 lakh crore in cumulative investments.
- Introduction of a 50% capital subsidy under the Production Linked Incentive (PLI) scheme.
- Establishment of dedicated semiconductor clusters and green energy plants to support manufacturing needs.
- Export incentives and tax rationalization to attract foreign direct investment and global partnerships.

Research, Innovation, and Talent Development

India is investing heavily in semiconductor R&D and talent development:

- IISc Bangalore received ₹3.34 billion to advance GaN technology, leading to the development of India's first electronic-mode GaN power transistor.
- DRDO achieved breakthroughs in indigenous SiC wafer production and GaN-based high-frequency devices.
- Academic-industry collaborations and skilling initiatives are being scaled up to support long-term growth. With over 20% of the global semiconductor design workforce based in India, the country is poised to lead in chip design and innovation.

Challenges and Outlook

Despite the progress, several challenges persist:

- High capital costs and dependency on imported raw materials.
- Need for a highly skilled workforce and advanced fabrication capabilities.
- Regulatory and logistical hurdles in setting up large-scale fabs.
- However, with sustained policy support, strategic global partnerships, and a growing domestic market, India's semiconductor industry is on a promising trajectory. The unveiling of the first "Made in India" chip by late 2025 is expected to mark a significant milestone in the country's journey toward becoming a semiconductor powerhouse.

Strategic Collaborations and Global Partnerships

India's semiconductor ambitions have been significantly bolstered by a wave of international collaborations in 2025. Notably, Tata Electronics signed a Memorandum of Understanding (MoU) with Germany's Robert Bosch GmbH to jointly develop advanced chip packaging and semiconductor manufacturing capabilities. This partnership will support Tata's upcoming assembly and testing facility in Assam and its semiconductor foundry in Gujarat, with a focus on vehicle electronics and high-performance computing.

Additionally, Micron Technology received government approval to establish a Special Economic Zone (SEZ) in Sanand, Gujarat, with an investment of ₹13,000 crore. This SEZ is expected to serve as a hub for high-value chip packaging and testing, further integrating India into the global semiconductor supply chain.

Market Outlook and Industry Momentum

India's semiconductor market is projected to reach $39.5 billion in 2025, with a compound annual growth rate (CAGR) of 16% through 2033. This growth is driven by rising demand across automotive, telecom, consumer electronics and industrial automation sectors. Integrated circuits (ICs) including analog, logic, micro and memory chips remain the dominant product segment, fuelled by the adoption of 5G, AI and IoT technologies.

Germany Scenario

Strategic Vision and Policy Framework

Germany has emerged as the epicentre of Europe's semiconductor ambitions in 2025, driven by a robust policy framework, strategic investments, and a clear vision to reduce dependency on non-European suppliers. The country is central to the European Union's goal of achieving 20% of global semiconductor production by 2030, a target supported by the €43 billion European Chips Act, with Germany contributing nearly half of the funding.

In July 2025, the German government unveiled a new high-tech agenda aimed at consolidating its leadership in semiconductor manufacturing. This includes plans for three new semiconductor plants, with official approvals expected by mid-year. The agenda also emphasizes the integration of semiconductors into AI, quantum computing and green energy systems, positioning Germany as a global innovation hub.

Industrial Expansion and Investment Highlights

Germany's semiconductor landscape is undergoing rapid transformation, with major global players expanding their footprint:

- TSMC, Bosch, Infineon, and NXP have launched the European Semiconductor Manufacturing Company (ESMC) in Dresden. This €10 billion+ project, backed by €5 billion in public subsidies, is a flagship initiative under the EU Chips Act.
- Intel's Magdeburg facility, previously delayed, is regaining momentum. Wolfspeed's Ensdorf plant is expected to resume development later in 2025.

These projects are part of a broader strategy to build a resilient, vertically integrated semiconductor value chain within Germany and the EU. Germany is also home to a dense network of SMEs, research institutions and startups, particularly in regions like Saxony, Bavaria and Baden-Württemberg, which are emerging as semiconductor innovation clusters.

Technological Innovation and Future-Readiness

Germany is not only scaling production but also investing in next-generation semiconductor technologies. The focus is on smart, energy-efficient chips for applications in:

- Electric vehicles and renewable energy system
- AI and quantum computing
- Industrial automation and robotics

A pilot project to develop supercomputers for vehicles is set to launch in late 2025, reflecting the country's ambition to lead in AI-driven mobility.

The government's broader innovation strategy includes:

- Establishing AI Gigafactories by 2027
- Launching a quantum communication satellite in 2025
- Supporting AI Robotics Boosters and software engineering programs

These initiatives aim to ensure that AI contributes 10% of Germany's GDP by 2030, transforming the country into a global leader in AI-integrated semiconductor applications.

Economic Performance and Workforce Development

Germany's semiconductor industry recorded a €12 billion turnover in 2023, with a projected 6%+ annual growth rate through 2027. The sector employs a highly educated workforce, with 60% of employees holding academic degrees. To sustain this momentum, the government is:

- Promoting cross-university training programs
- Standardizing cleanroom and lab infrastructure
- Encouraging SME participation in R&D and production

These efforts are designed to ensure a steady pipeline of talent and innovation, critical for long-term competitiveness.

Challenges and Strategic Outlook

Despite the positive trajectory, the industry faces several challenges:

- Supply chain vulnerabilities, especially for raw materials
- Delays in large-scale projects, such as Intel and Wolfspeed
- Global competition, particularly from the U.S.A. and China

However, Germany's proactive policy framework, strong industrial base, and commitment to innovation provide a solid foundation for overcoming these hurdles.

Looking ahead, Germany is expected to:

- Expand its role in global semiconductor supply chains
- Deepen public-private partnerships for commercialization
- Lead in green and AI-driven chip technologies

Conclusion

From January to July 2025, Germany has demonstrated remarkable progress in reshaping its semiconductor industry. With a clear strategic vision, robust investments, and a focus on innovation, the country is well-positioned to become a global semiconductor powerhouse. As the second half of the year unfolds, Germany's ability to execute on its ambitious agenda will be critical in determining its long-term leadership in this strategically vital sector.

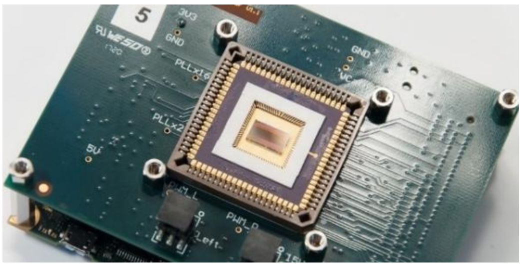
Opportunities for Indo-German cooperation in Microelectronics and Semiconductors

- Sensors
- CMOS Chip Design
- Power Electronics
- Semiconductor Packaging
- MEMS
- Microwave & Terahertz
- Optoelectronics
- System Reliability & Testing
- Skilling

1. Sensors

1.1. Introduction

Sensors are foundational components of modern electronics, enabling the detection, measurement and conversion of physical parameters into electrical signals. They are essential for applications ranging from industrial automation, mobility, healthcare, environmental monitoring and consumer electronics. Sensors are the backbone of the Internet of Things (IoT) and cyber-physical systems, creating smart, connected environments[1].



Credit: Fraunhofer IMS

1.2. Status Quo: Trends, Demands, Technological Advancement

- ### India:

  India's sensor ecosystem is characterized by a strong research base with a growing demand across sectors. Indian academia ranks among the global top five in IoT and sensor research, providing a solid foundation for innovation. Government initiatives like Digital India and Smart Cities have spurred development of indigenous sensors for agriculture, healthcare, and environmental monitoring. Multiple Indian academic institutions specialize in nano-sensors and IoT devices, translating lab results to real-world applications. A strong startup ecosystem is emerging, for example, an IIT-incubated venture Nanosniff recently commercialized a world's first microsensor-based explosive detector, a Made in India product that reduces reliance on imports. With policy support and industry collaboration, India is steadily building end-to-end capabilities in sensor design, fabrication, and deployment, positioning itself as a key player in the trillion-dollar IoT market.

- ### Germany:

  Germany is a global frontrunner in sensor technology, driven by its strengths in industrial automation, automotive engineering and Industry 4.0. The German sensor market is highly innovation-oriented, with key clusters in Bavaria, Baden-Württemberg and North Rhine-Westphalia hosting leading players. Trends include miniaturized MEMS-based sensors, optical sensors, gas and environmental sensors and multi-sensor fusion systems. Demand is growing for intelligent, networked, self-diagnostic sensors to support autonomous systems, predictive maintenance and sustainability goals. Research and commercialization of smart sensors is strongly supported by Fraunhofer Institutes like IIS, IMS, ENAS, EMFT and IPM[2], the VDE (Association for Electrical, Electronic & Information Technologies)[3] and the Federal Ministry for Economic Affairs and Climate Action (BMWK)[4].

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[1] *https://www.iis.fraunhofer.de/en/ff/sse/sensor-solutions.html*
[2] *https://www.ims.fraunhofer.de/en/Infrastructure/Center-for-Sensor-Technology.html*
[3] *https://www.vde.com/en*
[4] *https://www.bundeswirtschaftsministerium.de/Redaktion/EN/Dossier/innovation-policy.html*

1.3. Challenges

- ### India:

  India has made progress in Sensor research and development; significant challenges remain in establishing a strong manufacturing base and achieving widespread commercialisation. The future of Sensor in India hinges on continued government support, increased industry collaboration, and successful translation of research into marketable products.

- ### Germany:

  Despite Germany's technological edge, there is increasing global competition (notably from Asia), shortages of critical raw materials, cybersecurity concerns in sensor-integrated networks and the need for standardized interfaces for interoperability[5]. To address the bottleneck in sensor supply, Germany is working to scale its production to meet the surging demand for high-volume, cost-effective sensors, especially in the automotive and industrial IoT segments.

1.4. Indo-German Collaboration Opportunities

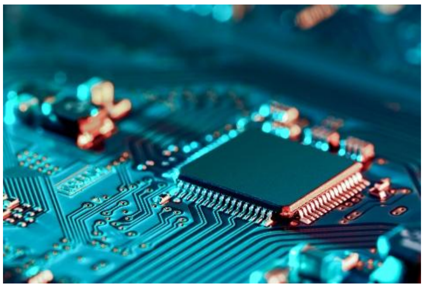
India, with its growing manufacturing base, digitalization drive and talent pool in embedded systems, offers synergies for joint R&D, manufacturing partnerships and co-development of sensor-based solutions. Opportunities exist in designing cost-effective sensors for automotive, industrial, renewable energy, healthcare applications, as well as for environmental monitoring and smart cities. Particularly, joint R&D in Image, Infrared and X-Ray sensors is of utmost importance as these find applications across many important sectors. German expertise in precision engineering and quality standards, coupled with India's scalability and market demand, creates a strong basis for cooperation. Joint skill development programmes and bilateral innovation platforms (for example through IGSTC)[6] can accelerate the Indo-German sensor ecosystem.

[5] *https://www.plattform-i40.de/IP/Navigation/EN/Home/home.html*
[6] *https://www.igstc.org/home/projects_call_text*

2. CMOS Chip Design

2.1. Introduction

Complementary Metal-Oxide-Semiconductor (CMOS) technology is the foundation of modern integrated circuits, powering processors, memory, sensors and a wide range of electronic devices. CMOS chip design enables the high-density, low-power and cost-effective realization of digital and mixed-signal systems. Its scalability and manufacturability have driven exponential advances in computing and communication technologies over the past four decades[7].



Credit: Fraunhofer IIS

2.2. Status Quo: Trends, Demands, Technological Stage

- ### India:

  India has nurtured a vibrant chip design sector, leveraging decades of expertise as a global semiconductor design hub. An estimated 20% of the world's semiconductor design engineers are of Indian origin, and virtually every leading chip firm operates R&D centres in India. Building on this talent, the country is shifting from service-oriented design to home-grown fabless innovation. The **India Semiconductor Mission (ISM)** and **Make in India** program provide generous incentives, including a Design-Linked Incentive (DLI) scheme, to support startups and MSMEs in developing indigenous chips. This push has yielded startups designing 5G radios, AI accelerators, and IoT SoCs, with notable successes like the first domestic 4G/5G modem chip. Academic initiatives (e.g. open-source processor projects) and industry-academic consortia are further strengthening the design ecosystem. With these efforts, India's semiconductor design trajectory is on an upward curve, aiming to move from a **"chips for others"** model to creating proprietary IP and products for the world.

- ### Germany:

  Germany maintains strong capabilities in CMOS design, supported by its advanced R&D ecosystem and a robust network of design houses, research institutions and universities[8]. The focus areas include low-power design, high-reliability automotive chips and secure processors for industrial control[9]. Demand for application-specific integrated circuits (ASICs), system-on-chips (SoCs), and power-efficient microcontrollers continues to grow, particularly in the automotive, industrial automation and medical technology sectors[10]. Key research is taking place at various Fraunhofer Institutes, Technical Universities and collaborations under the European Chips Act[11]. Initiatives like "Chipdesign Germany" and research centres in Saxony are driving the development of advanced chips, including chiplets and heterogeneous integration[12]. Overall, Germany is advancing to design nodes below 22nm for automotive and industrial-grade chips, with a push toward secure and trustworthy chip architectures.

[7] https://www.iis.fraunhofer.de/content/dam/iis/de/doc/il/ics/ic-design/fraunhofer-iis-integrated-circuits-and-systems-broschure.pdf
[8] https://www.zvei.org/en/press-media/publications/semiconductor-strategy-for-germany-and-europe-discussion-paper
[9] https://www.vde.com/en/press/press-releases/microelectronics-masterplan
[10] https://silicon-saxony.de/en/
[11] https://www.bmwk.de/Redaktion/EN/Downloads/P/positionspapier-mikroelektronik-en.pdf?__blob=publicationFile&v=4
[12] https://silicon-saxony.de/silicon-saxony-kein-chip-ohne-chip-design-deutschlands-streben-nach-technologischer-souveraenitaet/

2.3. Challenges

- ### India:

  India faces challenges in its aspiration to build Indian Fabless Chip companies even though 20% of global semiconductor design engineers are located in India. It is imperative that the local Fabless Chip companies come up so that the local fabs and ATMP units can be utilized by the domestic companies. The large domestic consumption of electronics products and setting up of large units by the global EMS companies offers a large market for the potential Indian Fabless Chip companies. It is expected that the setting up of semiconductor fabs, ATMP units and large domestic electronic companies shall give impetus to starting of Fabless Chip companies.

- ### Germany:

  Germany must actively work to maintain sovereignty over advanced design capabilities, given global consolidation of design IP and tool chains. Germany is strategically addressing the shortage of skilled design engineers and the increasing design complexity with sub-10nm nodes. To strengthen its ecosystem, Germany is working to reduce the dependency on foreign EDA (Electronic Design Automation). While Germany has world-class automotive and industrial chip design skills, it is focused on accelerating its capabilities in high-volume consumer-grade chip design to compete effectively with Asia and the USA.

2.4. Indo-German Collaboration Opportunities

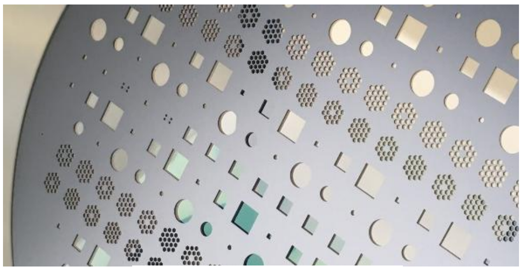
India's thriving semiconductor design talent pool and cost-effective engineering services provide a strong complementary base for German design houses[13]. Indo-German cooperation can focus on co-development of secure and energy-efficient SoCs for automotive and Industry 4.0 applications, collaborative skill development in VLSI and chip verification, and joint participation in EU–India technology programs. India's interest in building local design-led semiconductor ecosystems aligns with Germany's trusted supply chain ambitions, offering a win–win partnership[14].

[13] *https://ism.gov.in/*
[14] *https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4380*

3. Power Electronics

3.1. Introduction

Power electronics is the technology of converting, controlling and conditioning electrical power using solid-state electronics. It is vital for enabling energy-efficient systems in sectors like e-mobility, renewable energy integration, industrial automation and smart grids. Power electronics underpins the energy transition and is critical for achieving carbon-neutral targets.



Credit: Fraunhofer IISB

3.2. Status Quo: Trends, Demands, Technological Stage

- India:

  EV penetration is surging (EV sales +25–30% YoY in 2024)[15], and renewables (large solar/wind buildout) and smart-grid projects are driving demand for sophisticated power converters. Indian firms are partnering with global semiconductor leaders[16] and R&D centres[17][18] to adopt these trends. Domestic startups and research bodies are also exploring GaN/SiC capability to move to lighter, more efficient power modules. For example, national targets call for ~80% electrification of 2W/3W and 70% of commercial vehicles by 2030. Solar targets (hundreds of GW by 2030) and expansions in data centres and factories (Industry 4.0) similarly require advanced inverters and converters. Defense R&D explicitly cites GaN/SiC power modules as critical for future combat and satellite systems. Overall, the expanding automotive and energy sectors are key drivers. India power electronics market size reached USD 2.7 Billion in 2024 and expected to reach USD 4.3 Billion by 2033, exhibiting a growth rate (CAGR) of 5.28% during 2025-2033[19].

  Technological Stage: India's technical ecosystem is evolving but still maturing. At the device level, most of the Si, GaAs and SiC/GaN devices are imported. However, domestic firms are emerging e.g. CDIL opened India's first SiC component assembly line in 2024[20] and has MoUs with government fabs (SCL) to develop local wafer capabilities. Indian companies build EV inverters, solar inverters, battery management systems (BMS), and motor drives[21]. PSUs such as BHEL, BEL manufacture heavy power converters and radars for Defense and ISRO. Academic and R&D initiatives have expanded significantly, with the National Mission on Power Electronics Technology (NaMPET) under MeitY supporting research activities and facilitating the transfer of SiC/Si-based charging technologies to industry. Key global players (TI, Infineon, ST, Renesas) maintain R&D centres or

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[15] https://www.eetindia.co.in/tata-elxsi-partners-with-infineon-to-accelerate-ev-innovation-in india/#:~:text=This%20strategic%20collaboration%20aligns%20with,wheeler%20sales

[16] https://www.eetindia.co.in/tata-elxsi-partners-with-infineon-to-accelerate-ev-innovation-in-india/#:~:text=Tata%20Elxsi%20brings%20its%20design%2C,ICs

[17] https://www.cens.res.in/en/research/research-highlights

[18] https://www.cens.res.in/en/research/research-highlights

[19] https://www.imarcgroup.com/india-power-electronics-market#:~:text=Market%20Overview%3A

[20] https://www.powerelectronicsnews.com/cdils-sic-manufacturing-lineup-and-the-growth-in-the-semiconductor-industry-in-india/#:~:text=Silicon%20Carbide%20,of%20Wide%20Band%20Gap%20conductors

[21] https://www.renesas.com/en/about/newsroom/tata-elxsi-and-renesas-establish-next-generation-ev-innovation-center?srsltid=AfmBOoqrPJPEg1Jrl8mklPFjbyuCyHKiY4t2WrQoueGhqlbg_JiLooA0

partnerships in India, while design houses (Tata Elxsi, L&T, etc.) develop IP. The PLI schemes for semiconductors and auto components boost domestic power electronics, while MeitY's NaMPET mission focuses on WBG devices and advanced converters. Design-linked and production-linked incentives (PLI/DLI) encourage setting up fabs and module lines. Collaboration between research labs and industry – BEL with ISRO, C-DAC and VNIT with startups, and public-sector research (SCL, C-MET, DRDO) aims to close the technology gap.

- ### Germany:
  Germany is a global leader in power electronics, with a highly advanced ecosystem spanning research institutions, industry and standards organizations. The country's focus areas include wide-bandgap semiconductors (SiC, GaN), high-voltage power modules, and advanced inverter technologies for electric vehicles and renewables[22]. German industry is seeing strong demand for high-efficiency, high-reliability converters for wind and solar energy, fast-charging infrastructure and industrial drives. Clusters such as ECPE (European Centre for Power Electronics)[23] in Bavaria and the Fraunhofer Institutes like IISB, ISIT and ISE, lead research and application-oriented development. Overall, Germany is working toward higher power densities, improved thermal management and integrated power module packaging.

3.3. Challenges

- ### India:
  Despite growing demand and strong policy momentum, India's power electronics ecosystem faces significant structural and technological challenges. The most critical gap is the absence of domestic fabrication facilities for advanced power semiconductor devices such as SiC and GaN. The country remains heavily dependent on imports for raw materials like SiC substrates, GaN wafers, epitaxial layers, and process chemicals as well as for advanced packaging, particularly for high-voltage and thermally demanding applications.

  The ecosystem for wide-bandgap (WBG) technologies remains nascent, with limited domestic capabilities in IP ownership, semiconductor-grade equipment, and high-voltage testing and certification infrastructure. Shortages of skilled technicians and design talent trained in WBG device development further hinder innovation and scale-up. Additionally, high capital intensity, long gestation periods, and limited access to venture or risk capital discourage private investment in indigenous manufacturing. India's reliance on foreign IP and global supply chains poses strategic vulnerabilities. Addressing these gaps—through targeted investments in fabs, materials, talent development, and infrastructure—is essential for building a resilient and competitive domestic power electronics ecosystem.

- ### Germany:
  Germany must address the global shortage of critical materials like silicon carbide wafers, long qualification cycles for automotive-grade devices and competition from Asia in manufacturing scale[24]. Germany is working to consolidate fragmented supply chains for raw materials, manage energy costs for production and cultivate a robust talent pool of

[22] *https://www.iisb.fraunhofer.de/en/press_media/press_releases/pressearchiv/archiv_2024/pcim2024.html*
[23] *https://www.ecpe.org/*
[24] *https://www.ecpe.org/research/roadmaps-strategy-papers/roadmaps/*

skilled engineers with expertise in wide bandgap technologies[25]. Furthermore, Germany is aligning new power semiconductor designs with evolving EU environmental and recycling regulations[26].

3.4. Indo-German Collaboration Opportunities

India's growing renewable energy installations, e-mobility push, and infrastructure modernization offer a promising platform for joint efforts in power electronics[27]. Indo-German collaboration can focus on co-development of renewable energy integration, smart grid and microgrid technologies, material science and fabrication technologies, SiC and GaN-based power semiconductor devices and electric vehicle fast-charging systems. Indian universities and R&D labs, together with German industrial know-how, could build joint testing and certification facilities for advanced power electronics. Skilling programs on wide-bandgap device packaging, reliability testing and systems engineering could further strengthen bilateral cooperation.

[25] *https://www.power-and-beyond.com/whats-slowing-the-semiconductor-boom-a-view-from-the-engineering-front-line-a-619638fb75081a9798297e6e1584a447/#:~:text=The%20problem%20extends%20to%20the,high%20demand%20but%20short%20supply.*

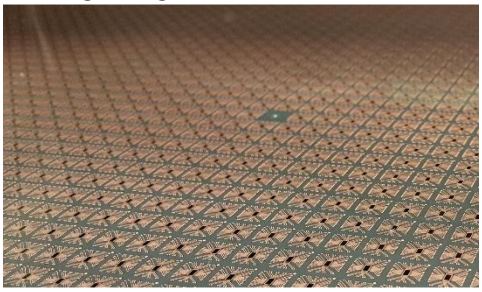
[26] *https://environment.ec.europa.eu/news/circular-economy-new-recommendations-national-authorities-increase-return-used-and-waste-mobile-2023-10-06_en*

[27] *https://mnre.gov.in/*

4. Semiconductor Packaging

4.1. Introduction

Semiconductor packaging involves enclosing and protecting integrated circuits to ensure their mechanical, thermal and electrical performance. Advanced packaging technologies enable higher device density, better signal integrity, and enhanced heat dissipation, all of which are critical for modern high-performance electronics[28]. Packaging is increasingly recognized as a key differentiator in semiconductor value chains as Moore's Law slows down[29].



Credit: Fraunhofer IZM

4.2. Status Quo: Trends, Demands, Technological Stage

- ### India:

India's packaging needs are driven by booming electronics and strategic sectors. In 2024, telecommunications (5G base stations, small cells, RF modules) alone accounted for ~32% of India's chip demand[30]. Electric vehicles and mobility programs are expanding automotive semiconductor requirements at ~25% CAGR, with silicon content per EV more than doubling (to ~$600). Consumer electronics (smartphones, IoT devices) and government "Make in India" incentives are boosting demand for local SoCs, PMICs and display-driver chip. Defense and aerospace programs further accentuate the need for reliable packaged chips. For example, Kaynes Semicon's upcoming Gujarat plant (6M chips/day) is explicitly targeting automotive, EV, telecom, consumer and mobile markets, reflecting these broad demand drivers[31]. India's semiconductor packaging industry is rapidly evolving under strong government support. The coming years will see new ATMP/OSAT lines come online (Sanand, Assam, UP), satisfying rising domestic demand from automotive, 5G, and defense sectors.

- ### Germany:

Germany has a strong base in advanced semiconductor packaging, driven by its expertise in automotive electronics, industrial automation and power semiconductors. The industry is moving toward advanced heterogeneous integration, 2D/3D packaging, and system-in-package (SiP) technologies[32]. German research institutes, especially Fraunhofer ENAS[33] and IZM, are global leaders in advanced packaging R&D, covering fan-out wafer-level packaging, embedded die and highly reliable automotive-grade packages[5]. Demand for advanced packaging is also growing in sectors such as renewable energy, medical devices

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[28] https://www.izm.fraunhofer.de/en/abteilungen/system_integrationinterconnectiontechnologies/arbeitsgebiete/fan-out-wafer-level-packaging.html

[29] https://www.csis.org/analysis/advanced-packaging-and-future-moores-law

[30] https://www.mordorintelligence.com/industry-reports/india-semiconductor-market#:~:text=Telecom%20base,image%20sensors%2C%20deepening%20domestic%20linkages

[31] https://www.india-briefing.com/news/setting-up-a-semiconductor-fabrication-plant-in-india-what-foreign-investors-should-know-22009.html/#:~:text=,electronics%2C%20telecom%2C%20and%20mobile%20phones

[32] https://blog.izm.fraunhofer.de/heterogeneous-integration/

[33] https://www.enas.fraunhofer.de/en/Business_Units/Process,_Device_and_Packaging_Technology/3D_MEMS_Packaging.html

and sensor systems[34]. The market is projected to grow at over 5.74% CAGR from 2024 to 2029.[35]

4.3. Challenges

- ### India:
  India's semiconductor packaging sector is undergoing rapid transformation, driven by robust government incentives and rising demand from automotive, 5G, and defense industries. New ATMP/OSAT facilities in Sanand, Assam, and Uttar Pradesh are set to boost domestic capacity. Despite this progress, key challenges persist—high capital requirements, dependence on imported materials, and a shortage of skilled manpower. However, significant investments from domestic players (Tata, Kaynes, Sahasra) and global giants (Micron, Foxconn, Renesas) are helping to bridge these gaps. India is steadily shifting from basic assembly to advanced packaging. By 2025–2030, the goal is to develop capabilities in 2.5D/3D packaging and chiplet integration, strengthening national security and enhancing supply chain resilience.

- ### Germany:
  Germany must overcome the global competition from Asian packaging foundries, limited domestic high-volume packaging capacity and dependency on imported substrates and packaging materials[36]. Germany is actively strengthening its advanced packaging capabilities to fully meet automotive reliability and traceability demands. Furthermore, Germany is prioritizing the training of skilled engineers specializing in system-in-package design, high-density interconnects and advanced materials.[37]

4.4. Indo-German Collaboration Opportunities

India's emerging semiconductor assembly and testing ambitions, supported by policy incentives under the Indian Semiconductor Mission, provide opportunities to collaborate with German players in packaging R&D, workforce training and high-reliability package qualification[38]. Indo-German cooperation could focus on co-developing packaging for automotive-grade semiconductors, power devices and MEMS sensors, with joint facilities for testing and reliability benchmarking. Germany's design and process expertise combined with India's scale and cost advantages could create a strong partnership in this critical value-chain segment.

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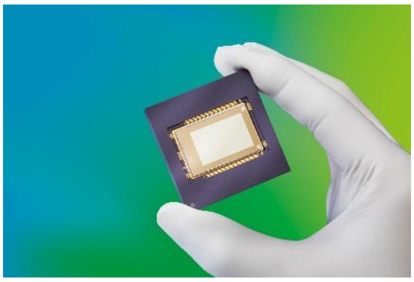
[34] https://www.ecpe.org/events/workshops-tutorials/workshops/workshop-details/evt/mdl/ed/554/eyJtZjEiOnsibWx1MSI6Inx8fHx8fHwifSwiZWYyIjp7ImVsdTEiOiIxfGx1ZmVkaXRtZWRpYWxpYnJhcnl8TWVkaWFMaWJyYXJ5RXZlbnRMaXN0fE1lZGlhTGlicmFyeXxldmVudExpc3R8Mjg5fDIwNTh8IiwiZXBjOSI6dHJ1ZX0sInJmMyI6eyJyb2FkbWFwTGlzdFVyaSI6Inx8fHx8fHwifSwiYmY0Ijp7ImJsdTEiOiJ8fHx8fHx8In0sImxkNSI6eyJsZHUxIjoifHx8fHx8fCJ9fQ==/?cHash=8362826384666889fe603330620c0a29
[35] https://www.bonafideresearch.com/product/6409099503/germany-semiconductor-advance-packaging-market
[36] https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Volkswirtschaft-Kompakt/One-Pager-2024-EN/VK-No.-246-July-2024-Semiconductor-value-chain.pdf
[37] https://www.bmwk.de/Redaktion/EN/Downloads/P/positionspapier-mikroelektronik-en.pdf?__blob=publicationFile&v=4
[38] https://ism.gov.in/

5. MEMS (Micro-Electro-Mechanical Systems)

5.1. Introduction

MEMS (Micro-Electro-Mechanical Systems) combine miniature mechanical structures, sensors, actuators and electronics on a single silicon substrate. They enable highly integrated, low-cost and energy-efficient devices for countless applications in automotive, medical devices, consumer electronics and industrial automation[39]. MEMS are critical enablers of the Internet of Things (IoT) and smart systems.



Credit: Fraunhofer IPMS

5.2. Status Quo: Trends, Demands, Technological Stage

- ### India:

  India has expertise in MEMS and microsensor systems under the National Program on Micro and Smart Systems (NPMASS), a government initiative by the Ministry of Electronics and Information Technology (MeitY) in India. It focuses on promoting research and development, creating awareness, and undertaking training programs in the field of Micro-Electro-Mechanical Systems (MEMS) and smart systems. The state-of-the-art design and microelectronics fabrication facilities created during 2010 -15. As a result, India was able to develop MEMS pressure sensors, MEMS inertial sensors and gyroscope, RF MEMS Switches and MEMS-based Gas Sensors. Presently, India MEMS Research focus on future generations 2D materials-based MEMS devices, SiC-based MEMS pressure sensors, and flexible MEMS biosensors for medical devices for health monitoring.

- ### Germany:

  Germany has a mature MEMS ecosystem, led by major industry players and Fraunhofer Institutes like IPMS, ENAS and IMS. The country is strong in pressure sensors, inertial sensors, microphones and MEMS-based RF devices[40]. German research focuses on next-generation MEMS for automotive safety, structural health monitoring and miniaturized medical devices[41]. Emerging trends include MEMS with integrated AI, multi-sensor platforms, and novel packaging approaches to improve robustness and reduce form factor[42]. The "MEMS2015" project, funded by the Federal Ministry of Education and Research (BMBF), is developing universal design methodologies to bridge gaps between electronics and mechanics, boosting innovation and market potential by up to 50% [43].

5.3. Challenges

- ### India:

  India is making strides in MEMS research and development; significant challenges remain in establishing a strong manufacturing base and achieving widespread commercialisation. The future of MEMS in India hinges on continued government support, increased industry collaboration, and successful translation of research into marketable products.

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[39] *https://www.enas.fraunhofer.de/en/Business_Units/Process,_Device_and_Packaging_Technology/MEMS_Technology_platforms.html*
[40] *https://www.ipms.fraunhofer.de/en/cleanrooms/mems-technologies-dresden/MEMS-components.html*
[41] *https://vdivde-it.de/en/department/electronics-and-microsystems*
[42] *https://www.enas.fraunhofer.de/en/departments/SP/research/3d-mems-packaging.html*
[43] *https://idw-online.de/de/news518304*

- ### Germany:

  Germany is working to optimize its MEMS production cost-competitive compared to Asian foundries[44]. Germany is actively addressing supply chain bottlenecks in specialty materials, accelerating long cycle times for automotive-grade qualification, and managing rising packaging complexity[45]. Additionally, Germany is focused on cultivating more skilled engineers trained in MEMS process integration, multi-physics simulation, and high-yield manufacturing techniques.[46]

5.4. Indo-German Collaboration Opportunities

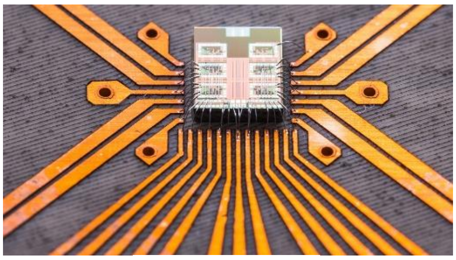
India's growing automotive, medical device and industrial sensor markets can partner with German players to develop MEMS solutions for emerging needs. Areas of joint interest include robust MEMS-based inertial sensors for mobility, low-cost gas and pressure sensors for industrial automation, inertial sensors, optical sensors and miniaturized healthcare diagnostics[47]. Indo-German cooperation could also expand into co-design of MEMS foundry processes, workforce training in design and testing and setting up testing or packaging capabilities in India with German know-how.

[44] https://www.ipms.fraunhofer.de/en/press-media/press/2024/300mm-Lab-to-Fab.html
[45] https://www.enas.fraunhofer.de/content/dam/enas/Dokumente/Deutsch/News_Events/ChemnitzerSeminare/seminar_39_sp_2024/15_Sandra-Gordzik_Industrialization-challenges-for-advanced-packaging-in-foundry-environment_240606.pdf
[46] https://www.forschungsfabrik-mikroelektronik.de/de/presse--und-medien/Presse/me-akademie.html
[47] https://www.imarcgroup.com/india-microelectromechanical-systems-market

6. Microwave & Terahertz

6.1. Introduction

Microwave and terahertz (THz) technologies cover the electromagnetic spectrum from about 300 MHz to several THz, enabling high-frequency communications, advanced imaging, radar, spectroscopy and sensing. These technologies are crucial for emerging applications in 5G/6G, automotive radar, security scanners and industrial process monitoring.



Credit: IHP, FMD

6.2. Status Quo: Trends, Demands, Technological Stage

- ### India:

  India is making strategic progress in microwave and terahertz (THz) technologies through coordinated R&D across national institutions. Under the CSIR-DELTA mission, CSIR-CEERI and IITs are working on THz communication, MEMS-based sensors, and GaN devices (CSIR-DELTA, 2024)[48]. DRDO labs such as MTRDC and DEAL have developed TWTs up to 0.22 THz and THz imaging systems (DRDO, 2024)[49]. SAMEER focuses on RF/microwave components for radar and telecom (SAMEER, 2024)[50]. TRAI has enabled experimental access to the 95 GHz–3 THz band under THEA, fostering trials in 6G and automotive radar (TRAI, 2024)[51]. These initiatives underline India's growing emphasis on compact, efficient THz systems for next-generation communication and sensing.

- ### Germany:

  Germany is among the leaders in microwave and terahertz technology, supported by a robust research ecosystem and advanced industrial base. Key focus areas include mmWave radar for automotive (e.g., 77 GHz systems), THz imaging for non-destructive testing and ultra-high-speed wireless communication for 6G[52]. Research Institutes such as Fraunhofer FHR, IAF, HHI and ITWM are driving innovation in GaN-based high-power devices[53], THz time-domain spectroscopy and THz sensors for material characterization[54]. German industry is witnessing growing demand for compact, integrated mmWave and THz solutions with low latency, high reliability and energy efficiency[55]. There is also significant emphasis on creating standardization frameworks and testing protocols for these high-frequency systems[56].

[48] *https://www.ttia2024.in*
[49] *https://www.drdo.gov.in*
[50] *https://www.sameer.gov.in*
[51] *https://techblog.comsoc.org/*
[52] *https://www.fhr.fraunhofer.de/en.html*
[53] *https://www.hhi.fraunhofer.de/en/pn-hardware/terahertz-communication.html#:~:text=THz%20communication%20is%20a%20complementary,partners%20from%20academia%20and%20industry.*
[54] *https://www.iaf.fraunhofer.de/en/researchers/electronic-circuits/high-frequency-electronics/t-kos.html*
[55] *https://www.itwm.fraunhofer.de/en/departments/mc/products-and-services/terahertz-imaging.html*
[56] *https://www.etsi.org/committee/thz#:~:text=Industry%20Specification%20Group%20(ISG)%20TeraHertz,(0.1%20%2D%2010%20THz)*

6.3. Challenges

- ### India:

  India faces several hurdles in advancing microwave and terahertz (THz) technologies. High component and instrumentation costs, combined with limited domestic semiconductor and packaging infrastructure, restrict development (Orbis Systems, 2024)[57]. THz signals are strongly attenuated by atmospheric absorption and obstructed by materials, limiting real-world applications (LightReading, 2024)[58]. Scaling lab prototypes to deployable systems is constrained by a lack of precision fabrication for waveguides and antennas (Springer, 2021)[59]. A shortage of engineers trained in mmWave/THz circuit design and testing further impedes progress (Reddit, 2025)[60]. Regulatory clarity and standardization efforts are still emerging, slowing commercial rollout and ecosystem development (Orbis Systems, 2024).

- ### Germany:

  Germany is strategically working to mitigate the high cost of THz components, limited commercial production capacity and complex material requirements for high-frequency packaging[61]. Germany is focused on scaling THz technologies, moving them from lab prototypes to reliable, mass-market solutions[62]. To support this, Germany is addressing the persistent shortage of engineers skilled in mmWave circuit design and THz measurement techniques. Germany is continuously prioritizing electromagnetic interference management and compliance with strict European safety regulations[63].

6.4. Indo-German Collaboration Opportunities

India's growing telecommunications, automotive, and security markets can offer a fertile ground for Indo-German cooperation on microwave and THz technologies[64]. Potential collaborations include joint R&D on affordable THz imaging systems, automotive radar sensors and testing platforms for 5G/6G frequencies[65]. Indo-German partnerships could also develop standardized measurement labs, share best practices in spectrum management and train engineers in advanced high-frequency design and testing. Germany's precision engineering strengths and India's market scale create a promising synergy for this advanced technology area[66].

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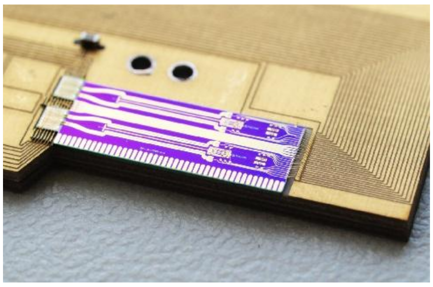
[57] *https://www.orbissystems.eu*
[58] *https://www.lightreading.com*
[59] *https://link.springer.com*
[60] *https://www.reddit.com*
[61] *https://www.hhi.fraunhofer.de/en/departments/pc/research-groups/terahertz-sensors-and-systems/research-topics.html*
[62] *https://cordis.europa.eu/project/id/644039/reporting*
[63] *https://single-market-economy.ec.europa.eu/sectors/electrical-and-electronic-engineering-industries-eei/electromagnetic-compatibility-emc-directive_en*
[64] *https://dot.gov.in/5g-india-2020*
[65] *https://www.hhi.fraunhofer.de/en/press/news/2025/fraunhofer-hhi-and-c-dot-launch-cooperation-for-the-future-of-telecommunications.html*
[66] *https://www.mea.gov.in/bilateral-documents.htm?dtl/39113/Joint+Statement+Second+Meeting+of+the+IndiaEU+Trade+and+Technology+Council+New+Delhi+February+28+2025*

7. Optoelectronics

7.1. Introduction

Optoelectronics refers to devices and systems that source, detect and control light, combining optical and electronic functions on the same platform. These technologies are the backbone of high-speed communication networks, advanced sensing, medical diagnostics, industrial process monitoring and renewable energy applications like photovoltaics. With the convergence of photonics and microelectronics, optoelectronics is driving innovation across nearly all sectors of the digital economy.



Credit: Fraunhofer HHI

7.2. Status Quo: Trends, Demands, Technological Stage

- ### India:

  India's optoelectronics market is witnessing robust growth, projected to reach $3.75 billion in 2025[67]**.** This growth is driven by rising demand across sectors such as consumer electronics, telecommunications, automotive, and healthcare, with increasing adoption of LEDs, sensors, and photodetectors for energy-efficient and high-performance applications[68]. Key drivers include the expansion of data communication infrastructure, surge in smart devices, rapid 5G rollout, and the integration of optoelectronic components in vehicles and medical devices. Leading academic institutions (such as IITs, IISc) and national laboratories (CSIR, DRDO, ISRO) are actively contributing to innovations in materials like perovskites, III-V semiconductors, and lithium niobate for electro-optic and nonlinear applications[69][70][71]. Government initiatives like the National Quantum Mission and Digital India push are further stimulating indigenous development of photonic chips and components[72][73].

- ### Germany:

  Germany holds a global leadership position in optoelectronics, with robust clusters around photonics, laser systems and optical sensors[74]. Demand is rising for high-performance optoelectronic components for datacentres, LiDAR systems for autonomous driving and optical sensors for industrial IoT[75]. Fraunhofer Institutes such as IPMS, HHI, IZM and IMS are advancing cutting-edge optoelectronic packaging, photonic integrated circuits, silicon photonics and laser-based communication systems[76][77][78][79]. Ongoing R&D focuses on high-speed transceivers, energy-efficient optical interconnects and robust photonic sensors, supported by initiatives under the Photonics21 platform[80]. Germany's ecosystem benefits

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[67] *https://www.statista.com/outlook/tmo/semiconductors/optoelectronics/india*
[68] *https://www.6wresearch.com/industry-report/india-optoelectronic-components-market*
[69] *https://www.cense.iisc.ac.in/*
[70] *https://www.isro.gov.in/LEOS.html*
[71] *https://sites.google.com/view/tsingh-step-iitdelhi/news?utm_source=chatgpt.com*
[72] *https://www.pib.gov.in/PressReleasePage.aspx?PRID=2116339*
[73] *https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1969480*
[74] *https://www.gtai.de/resource/blob/81758/8d1e83cb9eeaeccf0f1cb60c8a798f4f/photonics-in-germany-2019-data.pdf*
[75] *https://www.ipms.fraunhofer.de/en.html*
[76] *https://www.ipms.fraunhofer.de/en/Components-and-Systems/Integrated-Photonics.html*
[77] *https://www.hhi.fraunhofer.de/en/departments/pc.html*
[78] *https://www.izm.fraunhofer.de/en/abteilungen/system_integrationinterconnectiontechnologies/arbeitsgebiete/photonic-packaging.html*
[79] *https://www.ims.fraunhofer.de/en/Core-Competence/Technology/PICs.html*
[80] *https://www.photonics21.org/*

from strong academic–industrial partnerships and standardized certification processes for optoelectronic components[81].

7.3. Challenges

- ### India:

  Large-scale domestic manufacturing is restricted by the dependence on imported advanced materials, components, and critical fabrication equipment, which also makes the country more susceptible to supply chain disruptions worldwide[82]. The ecosystem for foundries and fabrication facilities is developing, with limited access to state-of-the-art facilities for prototyping and mass production of photonic integrated circuits (PICs)[83]. Additionally, India faces a lack of advanced PIC fabrication and packaging facilities, weak industry–academia collaboration and commercialization pathways, and limited access to global photonic foundry PDKs, all of which hinder the growth of a robust optoelectronics ecosystem.

- ### Germany:

  Germany is focused on overcoming the high costs of scaling up silicon photonics production, shortage of skilled photonics engineers and global competition from Asian manufacturers. Supply chain dependencies for photonic substrates and packaging materials are also a vulnerability. Germany is working to address challenges in integrating photonic chips with traditional CMOS systems and ensuring their mass reliability testing.

7.4. Indo-German Collaboration Opportunities

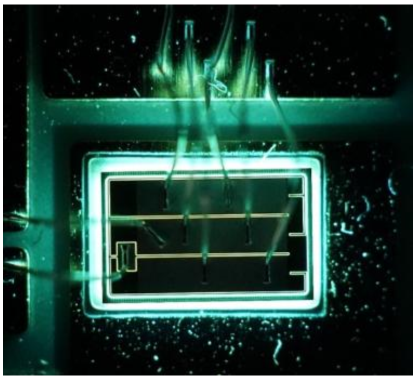
India's rapidly growing telecommunications, medical diagnostics and renewable energy markets create rich opportunities for cooperation with German optoelectronic innovators[84]. Joint projects could focus on photonic sensor applications for smart manufacturing, low-cost optical communication solutions for 5G and beyond, and co-development of LiDAR and medical imaging technologies. Bilateral skilling programs in photonics design, packaging and testing, along with shared labs for optoelectronic component qualification could strengthen collaboration. Additionally, establishing Indo-German research hubs for photonic integrated circuits (PICs), silicon photonics, and quantum photonics can drive innovation and knowledge exchange. Collaborative efforts in standardizing components, sharing foundry access, and co-developing packaging solutions can deepen technological cooperation and advance the Indo-German partnership.

[81] *https://www.vde.com/en/press/press-releases/data-centers-ai-photonic*
[82] *https://semiconductorinsight.com/report/india-optical-component-market/?utm_source=chatgpt.com*
[83] *https://www.marketresearch.com/Ken-Research-v3771/India-Photonics-Integrated-Circuits-Outlook-40720405/*
[84] *https://www.pib.gov.in/PressReleasePage.aspx?PRID=2126449*

8. System Reliability and Testing

8.1. Introduction

System reliability and testing are critical pillars of the electronics and semiconductor industry, ensuring that devices perform their intended functions safely and consistently under a wide range of conditions. Reliability engineering focuses on predicting, designing and validating system performance over its operational life, while testing involves verifying and screening at component, module and system levels. These practices are vital for automotive, aerospace, medical and industrial electronics where failures can have severe consequences[85].



Credit: Fraunhofer ENAS

8.2. Status Quo: Trends, Demands, Technological Stage

▪ India:

With the expansion of its electronics and semiconductor initiatives, India is placing new emphasis on system reliability and testing to meet international quality benchmarks. Traditionally, organizations like ITI Ltd. have operated 24×7 reliability engineering labs for telecom and defense hardware, offering environmental stress screening, vibration, thermal cycling, and other MIL-STD tests for over two decades. Building on this foundation, today's focus is to establish state-of-the-art semiconductor test facilities domestically. The India Semiconductor Mission explicitly encourages development of domestic testing and certification infrastructure, alongside fabs and ATMP units. Private Indian firms such as Tessolve now provide end-to-end chip testing services, from prototype characterization to high-volume automated testing, for global clients, indicating growing competence in this arena. Moreover, partnerships with international specialists are helping Indian labs adopt best practices in failure analysis and reliability qualification. Academic programs are also emphasizing reliability engineering and EDA-based test design. Through these combined efforts, India is enhancing its capability to rigorously validate chips and systems (for thermal stability, longevity, and safety) before they hit the market. This strengthening of the reliability and testing ecosystem instils greater confidence in "Made in India" semiconductors and electronics, ensuring they adhere to the stringent standards required by both domestic and export markets.

▪ Germany:

Germany is internationally recognized for its rigorous approach to system reliability and testing, driven by its dominant automotive, industrial automation and power electronics sectors[86]. The country's focus is on advanced accelerated stress testing, physics-of-failure modelling and digital twins for predictive reliability[87]. Testing trends include automated test platforms, machine-learning-based defect detection and in-situ monitoring of field-deployed systems[88]. Fraunhofer IZM, ENAS and IMWS work heavily in failure analysis, environmental testing and lifetime modelling. Germany also has strong standardization

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[85] *https://www.izm.fraunhofer.de/en/abteilungen/environmental_reliabilityengineering.html*
[86] *https://www.zvei.org/en/subjects/robustness-validation-general?l=1&cHash=0507a4a7a5c770c034cf6918bf404b18*
[87] *https://www.imws.fraunhofer.de/en/presse/pressemitteilungen/2020/new-methods-for-failure-analysis-of-electronic-components-and-sy.html*
[88] *https://www.vde.com/tic-en/industries/automation-technology-measuring-and-laboratoy-equipment*

efforts, aligned with VDE and IEC frameworks to harmonize testing and reliability certification for new technologies such as wide-bandgap semiconductors and advanced packaging[89].

8.3. Challenges

- ### India

  The India Semiconductor Mission has bolstered semiconductor fabs and ATMP units in the country. India is coming up with complex devices and packages where system reliability & testing capabilities are being built on a larger scale. India has to next focus on Advanced Packaging and Compound Semiconductors. India needs to multiply and build System Reliability and Testing capabilities in Microelectronics, Semiconductor and Packaging to meet the growing demands of the industry, investing in the next generation technologies at its research and academic institutions. The automotive, aerospace, medical, industrial electronics and defence sectors require specific attention.

- ### Germany:

  Germany is working to manage the increasing complexity of systems with heterogeneous integration, higher power densities and thermal constraints[90]. Germany is actively addressing the growing concern of a shortage of skilled engineers in reliability engineering and test automation[91]. It is also working to mitigate the high costs and long qualification cycles of testing advanced systems (such as those for automotive safety standards like ISO 26262), which currently is placing burden on SMEs and slow time-to-market[92]. Germany must also address new challenges in cybersecurity reliability for network-connected devices[93].

8.4. Indo-German Collaboration Opportunities

India's expanding electronics manufacturing ecosystem and interest in building testing and certification infrastructure create synergies with German expertise[94]. Indo-German collaborations could include co-developing accelerated reliability test protocols for harsh environments, joint research on predictive maintenance and AI-driven failure analysis and setting up shared test centres for power electronics, MEMS and automotive-grade systems. Training programs in advanced reliability engineering, field-data analytics and design-for-testability could also be mutually beneficial.

[89] *https://tc56.iec.ch/dependability-standards/*
[90] *https://www.plattform-i40.de/IP/Navigation/EN/Home/home.html*
[91] *https://www.hannovermesse.de/en/news/news-articles/increasing-shortage-of-electrical-and-electronic-engineers-in-germany*
[92] *https://www.tuvsud.com/en-in/store/academy-in/sectors/automotive/0008-ISO26262-functional-safety-for-engineers-level*
[93] *https://www.bsi.bund.de/EN/Service-Navi/Publikationen/Lagebericht/lagebericht_node.html*
[94] *https://www.meity.gov.in/*

9. Skilling

9.1. Introduction

Skilling in electronics and semiconductors is crucial to build a resilient, competitive and innovation-driven industry. With technologies evolving rapidly, from advanced chip design to smart manufacturing and packaging, developing a skilled workforce is vital to address talent gaps and maintain technological sovereignty. This includes engineers, researchers and operators trained across the value chain from materials to systems.

Credit: FMD

9.2. Status Quo: Trends, Demands, Technological Stage

- ### India:

  India recognizes that a skilled workforce is the cornerstone of its ambitions in semiconductors and advanced electronics. The country has launched comprehensive talent development programs to prepare engineers and technicians for every stage of the value chain. Notably, the **Chips to Startup (C2S)** program aims to train 85,000 engineers in VLSI and embedded system design over five years, involving over 100 universities and R&D centers nationwide. This is complemented by longstanding initiatives like the Special Manpower Development Program (SMDP) that have seeded VLSI curricula in academia since the 1990s. Top institutions (IITs, IISc, BITS Pilani and others) now offer specialized degrees in microelectronics, semiconductor manufacturing, and photonics, often in collaboration with industry. To provide practical exposure, students are encouraged to participate in chip design tape-outs, internships at fabs, and hands-on projects (some institutions even facilitate chip fabrication through programs with SCL or global foundries). Government and industry are also introducing certification courses aligned with international standards and emerging areas (e.g. courses on chip packaging, MEMS, and AI for chip design). Additionally, companies like **Tata Electronics** have started sending cohorts of engineers abroad for training in semiconductor fab operations, ensuring knowledge transfer from more mature ecosystems. Through the **Digital India** and **Skill India** initiatives, modern e-learning platforms and hackathons are further broadening access to semiconductor education. India's approach to skilling is thus holistic, combining theoretical rigor with practical training, creating a large, industry-ready talent pool that will drive the country's semiconductor and high-tech aspirations in the years to come.

- ### Germany:

  Germany has a strong tradition of technical education and apprenticeships through its dual vocational training system[95]. For semiconductors and electronics, specialized programs exist at Universities complemented by industry-led qualification initiatives[96]. Fraunhofer Institutes such as FMD, IIS, ENAS, IZM, IPMS and Academy play a key role in bridging academic knowledge with hands-on industry skills, offering specialized training modules on chip design, packaging, MEMS, photonics and reliability

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[95] *https://www.bmbf.de/EN/Education/ContinuingEducationAndTraining/ContinuingVocationalEducationAndTraining/continuingvocationaleducationandtraining_node.html*

[96] *https://www.zvei.org/en/association/sections/semiconductors-section#:~:text=Our%20topics,Design/development%20and%20test%20benchmark*

engineering[97][98][99][100][101][102]. Germany is also investing in upskilling programs for wide-bandgap devices, advanced testing and Industry 4.0 applications[103]. Initiatives under the "MINT" education strategy promote STEM careers among youth to secure the future talent pipeline[104].

9.3. Challenges

- ### India:

  India's manpower in the technology sector has largely been employed by the services sector and has been accordingly skilled. With the start of India Semiconductor Mission, the manpower is now required for semiconductor manufacturing, ATMP and Indian fabless chip companies. There is a now renewed interest in design and manufacturing in the area of Sensors, MEMS, Photonics, Microwave and Terahertz, Power Electronics, Advanced Packaging, etc. to cater to the burgeoning domestic market and address the global market. This opens up multiple avenues for cooperation between India and Germany at the academia, research and industry level.

- ### Germany:

  Germany needs to strengthen its workforce of highly skilled engineers and technicians, especially in Chip design, advanced packaging and power electronics[105]. There is also a need to update training curriculum more rapidly to match emerging technologies like AI-driven chip verification and quantum electronics[106]. Germany is working to create a framework to retain skilled staff in the face of global competition by addressing diversity gaps in technical professions [107].

9.4. Indo-German Collaboration Opportunities

India's large, youthful engineering workforce and Germany's advanced training frameworks provide a strong basis for joint skilling programs. Indo-German cooperation can include bilateral exchange programs, co-developed curriculum on semiconductor design, packaging and system testing, and establishment of joint Centres of Excellence[108]. German experience in dual education can help India scale vocational training in semiconductor fabs and ATMP (Assembly, Testing, Marking and Packaging) facilities[109]. Collaborative upskilling in emerging areas like photonics, MEMS based sensors and compound semiconductors can foster a globally competitive workforce[110].

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[97] https://www.forschungsfabrik-mikroelektronik.de/en/Range_Of_Services/Additional-Services/collaborations-with-universities.html
[98] https://www.iis.fraunhofer.de/en/ff/sse/bavarian-chip-design-center/ic-design-talents.html
[99] https://www.enas.fraunhofer.de/en/jobs.html#3
[100] https://www.izm.fraunhofer.de/en/news_events/trainings-and-workshops.html
[101] https://www.ipms.fraunhofer.de/en/jobs/students.html
[102] https://www.academy.fraunhofer.de/en/continuing-education.html
[103] https://www.marketsandmarkets.com/ResearchInsight/germany-smart-manufacturing-market.asp
[104] https://www.bmbf.de/EN/Education/EarlyEducation/MINT-STEM/mint-stem_node.html
[105] https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2023/Februar/Studie_Fachkraeftemangel-Halbleiterindustrie/Studie-Halbleiter-Fachkraefte.pdf
[106] https://www.google.com/search?q=https://www.bmbf.de/SharedDocs/Publikationen/DE/FS/1086286_Rahmenprogramm_FITS2030_en.pdf
[107] https://www.perspektiveausland.com/auswanderung/deutschlands-talentflucht-treibt-immer-mehr-hochqualifizierte-in-die-auswanderung
[108] https://international-partnerships.ec.europa.eu/countries/india_en
[109] https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2117925
[110] https://economictimes.indiatimes.com/jobs/fresher/meity-ties-up-with-iits-for-skill-development-to-boost-semiconductor-sector/articleshow/117046111.cms?from=mdr

Key Policies and Programmes (India and Germany)

India

Semicon India Programme India Semiconductor Mission	• To build a vibrant semiconductor and display ecosystemglobal hub for electronics manufacturing and design, reducing import dependence and promote technological self-reliance. • Schemes under ISM such as (i) Setting up Semiconductor Fabs (ii) Display Fabs (iii) Compound & Discrete Semiconductor Fabs & OSAT / ATMP facilities (iv) DLI scheme for semiconductor chip design.
PLI Scheme for IT Hardware & Electronics	• Provide incentives to boost electronics and IT manufacturing and attract large investments in global value chain.
Electronics Manufacturing Clusters (EMC 2.0)	• To promote the development of world-class infrastructure and common facilities for the electronics industry, attracting investment and boosting domestic manufacturing and exports in the ESDM sector. This includes setting up both Electronics Manufacturing Clusters (EMCs) and Common Facility Centers (CFCs) to create a conducive ecosystem for the electronics industry.
National Mission on Power Electronics Technology (NaMPET)	• To provide the country with capability to become a dominant player in Power Electronics Technology at the global level.
National Policy on Electronics 2019 (NPE 2019)	• Make India a global hub for electronics system design and manufacturing (ESDM).
Skill India Programme	• Create a skilled workforce for electronics, semiconductors, and related high-tech sectors.
Digital India	• Drive digital infrastructure, e-governance and electronics production capacity.
Make in India	• Strengthen domestic manufacturing including semiconductors, electronics, and allied sectors.

Germany

Initiative	Objective
European Chips Act	•Strengthen Europe's semiconductor manufacturing capacity, R&D, design sovereignty and supply chain resilience
IPCEI Microelectronics(Important Project of Common European Interest)	•Support large-scale, cross-border strategic microelectronics projects; build European leadership in critical technologies.
Germany's National Semiconductor Strategy	•Expand domestic chip design, R&D, pilot production and packaging to boost resilience.
ChipDesign Germany Initiative	•Strengthen domestic design ecosystems and skills, develop advanced chip architecture capabilities in Germany.
Photonics21 Platform	•Advance Europe's photonics, optoelectronics, and laser-based systems for industrial competitiveness
ZEUS Programme (Future-proof, Efficient, and Sustainable Semiconductor Technologies)	•Support energy-efficient, environmentally friendly semiconductor tech for the green and digital transitions.
High-Tech Strategy 2025	•Foster R&D on key enabling technologies including microelectronics, photonics and AI.
Horizon Europe (Key Digital Technologies KDT JU)	•Fund collaborative research and innovation on next-gen electronics, microelectronics and embedded systems.
MEMS2015 Programme	•Support German industry leadership in MEMS, focusing on manufacturing, packaging, and sensor innovation.
Digital Strategy Germany	•Strengthen Germany's digital infrastructure and skills, including semiconductors as a key enabler for Industry 4.0.

Conclusion

Indo-German cooperation in semiconductors and microelectronics is multifaceted, strategically aligned and poised for further expansion, promising mutual benefits in technology leadership, economic growth and supply chain resilience. During the meeting of PM Narendra Modi and then German Chancellor Mr. Olaf Scholz in October 2024, India and Germany released the Roadmap on cooperation on Innovation and Technology with focus on AI, Semiconductors and Clean Energy. The Indo-German Strategic Partnership has seen impressive growth, with new investments exceeding 1 billion EUR across several key sectors. Much of this funding supports India's semiconductor projects and green technology development, with Germany providing both financial and technical support to help strengthen India's domestic semiconductor industry.

Examples of cooperation

Infineon and CDIL: Flagship collaboration between German semiconductor giant Infineon Technologies and India's CDIL Semiconductors. Infineon supplies silicon wafers to CDIL, which are then processed and packaged into power chips for use in sectors such as renewable energy, automotive and energy-efficient appliances. This partnership not only bolsters the "Make in India" initiative but also positions India as a future hub for semiconductor excellence, with initial production aimed at the domestic market and plans for global exports. Such collaborations leverage German technological expertise and India's growing manufacturing capabilities, fostering innovation and accelerating the development of a robust domestic semiconductor industry.

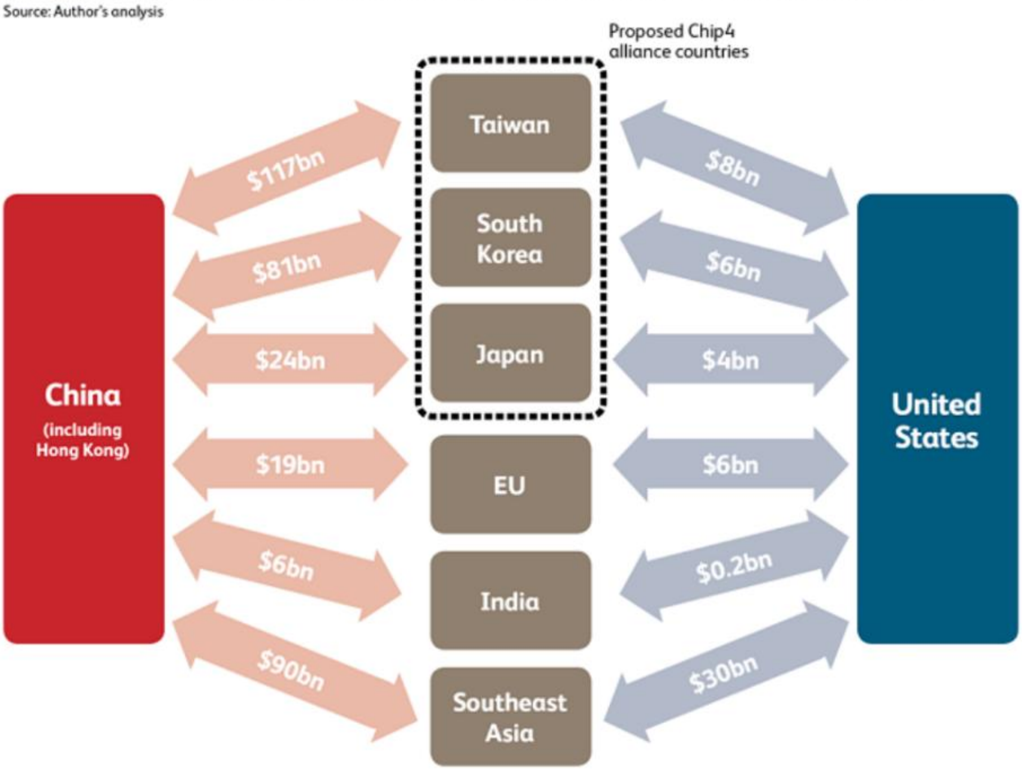
Fraunhofer C-DOT, EPIC and C-MET:

Beyond manufacturing, the Indo-German partnership extends to research, innovation and talent development. German research institutions, such as the **Research Fab Microelectronics Germany (FMD) of the Fraunhofer Microelectronics Alliance [Fraunhofer Gesellschaft]** through partnerships with India Institutions such as CMET, C-DOT and EPIC, is identifying opportunities in India to drive advancements in sensor systems, power electronics, packaging, chip design and skilling. Focus is on establishing several joint initiatives like Indo-German research partnerships, competence centres, university-research-industry partnerships, and multi-project wafer services, enabling Indian companies to develop and prototype new microelectronic applications cost-effectively.

The need for a stronger Indo German cooperation:

The global semiconductor market has reached sales of $627.6 billion in 2024 and projected to reach $700.9 billion in 2025, a 13.8% increase over 2024. The forecast indicates a CAGR of 8.71% between 2025 and 2029 potentially reaching a market volume of $980.82 billion by 2029.The size of the worldwide semiconductor market in 2021 was estimated to be US$1.8 trillion. More than 20 percent of the world's GDP is attributable to the semiconductor industry's impact on the global economy. No single country can aspire to cover the entire value chain of semiconductor production and will need "friendshoring". The semiconductor industry is highly interconnected, with different countries specializing in various stages of production. China is a major player in raw materials, manufacturing, and specific chip types. Global supply chains are being reorganised, as China and USA are at a trade war, and Korea may suffer losses due to the Chip 4 alliance. (See figure below).

FIGURE 1 TRADE CONNECTIONS AMONG KEY PLAYERS IN THE GLOBAL SEMICONDUCTOR INDUSTRY
Source: Author's analysis



Source: https://www.globalasia.org/v17no4

Technological Expertise:

While India and Germany are making strides, US, South Korea and China have a head start in certain areas, especially in advanced chip manufacturing. Here Germany and India can partner, with Germany bringing technology and India providing scale.

Increased Self-Reliance:

Both countries are investing in domestic semiconductor manufacturing, aiming to reduce dependence on foreign sources. While they continue their journey of Tech Sovereignty, both countries can craft "friend shoring strategies" to retain their technological supremacy in specific areas and align on complementary strengths. For example, sensor capabilities from Germany and telecommunications from India. Germany and India can also partner on specific capabilities along the value chain in a complementary manner. They can leverage their strengths and focus on specific areas like design, materials, or advanced manufacturing. Both countries can create a combined innovation ecosystem consisting of fundamental research capability, start-ups and qualified young workforce from India, with the applied research capability, tech-savvy Mittelstand and engineering excellence from Germany.

In conclusion:

The aim to significantly reduce their reliance on some countries and build stronger, more resilient global supply chains requires sustained investment, strategic partnerships, and a focus on building a robust domestic semiconductor ecosystem.

Key areas of existing cooperation between India and Germany include:

- Supply chain integration and technology transfer for chip manufacturing
- Joint research and development in micro- and nanoelectronics
- Talent mobility and skill development programs

Potential areas of cooperation between India and Germany include, but not limited to:

- Establishing local supply chains and manufacturing capabilities for sensor manufacturing, particularly for Automotive, Healthcare and Environmental Applications.
- Advanced packaging and assembly
- Collaborative research on next-generation semiconductor materials
- Expansion of design and prototyping services
- Development of IoT enabled - smart manufacturing solutions

The imperative of joining forces to create a paradigm shift from monopolistic countries to a larger framework of collaborative research and innovation is real and present, and Germany and India are uniquely positioned to leverage their individual strengths and gain a larger share of the significant growth markets.

Annexure

A. Competencies and Offerings of Fraunhofer:

Competencies

Topic	Advanced Research Competencies at Fraunhofer for industry-driven application
Sensors	▪ Profound in-depth knowledge in manufacturing sensors and integration of sensors in complex systems ▪ Sensor system design, including reliability engineering and testing for harsh environments ▪ Fully integrated sensor solutions (e.g., MEMS on CMOS) and hybrid sensor systems ▪ Embedded AI algorithms for smart sensing and data fusion ▪ Comprehensive sensor characterization (optical, acoustic, electrical), using non-destructive testing and reliability assessment under multiple stress scenarios
CMOS Chip Design	▪ Advanced analogue, mixed-signal, and RF CMOS circuit design. ▪ Low-power, high-performance digital architectures for AI and embedded systems. ▪ Design-for-reliability and radiation-hardened CMOS circuits. ▪ Integration of CMOS with MEMS, photonics, and sensor interfaces. ▪ IP blocks and ASIC design platforms for rapid prototyping and validation.
Power Electronics	▪ Expertise in materials and processing for SiC, GaN, and emerging WBG semiconductors. ▪ Cleanroom infrastructure for Si-, SiC-, and GaN-based device fabrication. ▪ Integrated 150 mm SiC production line; 200 mm Si-based platforms for GaN. ▪ Advanced device concepts (e.g., vertical GaN transistors, AlN, Ga_2O_3) for fast switching. ▪ Heterogeneous-system-integration as well as characterization of single devices, integrated modules or complete systems.
Semiconductor Packaging	▪ Advanced wafer-level and panel-level packaging technologies. ▪ 2.5D/3D integration including through-silicon vias (TSVs) and interposers. ▪ Thermal management, advanced materials, and reliability engineering for packages. ▪ Embedded passive and active components in package substrates. ▪ High-density interconnect design and heterogeneous system integration.
MEMS	▪ Design and simulation of MEMS structures and systems, including multi-physics modelling. ▪ Advanced MEMS fabrication processes (bulk, surface, Silicon-on-Insulator technologies). ▪ Advanced Packaging and Silicon Micro Patterning and Methods of MEMS/NEMS Packaging. MEMS integration with CMOS and heterogeneous packaging. ▪ MEMS-based sensing and actuation for automotive, industrial and medical applications. ▪ Testing, reliability analysis, and calibration of MEMS devices under harsh conditions.

Microwave & Terahertz	▪ Packaging and heterointegration expertise for high-frequency and THz applications. ▪ Design and development of advanced devices, circuits, and systems up to the THz regime. ▪ Access to Si-based and compound-semiconductor cleanrooms (Si, SiGe, InP, GaN/SiC, InGaAs/GaAs) for HBTs, HEMTs, passive structures and MMICs. ▪ Integration of III-V materials and InP-based HBT BiCMOS technologies into Si-based platforms. ▪ Comprehensive test and characterization capabilities, including reliability assessment in harsh environments.
Optoelectronics	▪ Design and realization of optoelectronic systems, including Tbit/s-speed communication solutions. ▪ Full signal-chain expertise from emitter, modulator, receiver to fully integrated systems. ▪ Broad material processing know-how (Si, compound semiconductors, polymers) and advanced passive/active device manufacturing; wide ranging Portfolio of different Laser Wavelengths: GaAs-based Laser (wavelength 620 – 1180 nm), InP-based Laser (~ 1.5 µm) and III-V-semiconductor Laser with wavelengths in the range of 2-11 µm. ▪ Heterogeneous integration of III-V materials on Si platforms with advanced packaging, Wafer Level Capping & Advanced Substrate/Interposer technologies. ▪ Characterization, reliability and degradation testing of complete optoelectronic systems under diverse stress conditions.
System Reliability & Testing	▪ Accelerated lifetime testing, failure analysis and predictive modelling for electronic systems. ▪ Reliability testing under multi-stress conditions (thermal, mechanical, humidity, vibration, radiation) ▪ Advanced non-destructive evaluation techniques for component and system-level defect detection. ▪ Qualification and standardization methods for system safety and functional performance. ▪ Development of digital twins and AI-based tools for reliability prediction, monitoring and diagnostics.
Skilling	▪ Development of industry-aligned curriculum and hands-on training modules across the semiconductor value chain. ▪ Implementation of dual education concepts combining academic theory with practical lab and fab experience. ▪ Specialized courses on emerging technologies such as AI in chip design, MEMS, photonics and advanced packaging. ▪ Certification programs and skill assessments aligned with international standards. ▪ Support for workforce upskilling and reskilling, including simulation-based learning and digital education tools.

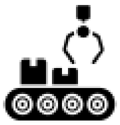
Offerings:

- Direct Industrial contract research (R&D projects, Technology consulting, Feasibility studies, Technology and process development, Pilot production)
- Technology Transfer (Licensing of technologies and processes)
- Services for Manufacturers (Development of demonstrators and prototypes, Technology services)
- Cooperative Projects (R&D projects jointly funded by public authorities and industry)
- Technology Consulting to create an innovation ecosystem on thematic topic

B. Value Proposition of Fraunhofer for various stakeholders:

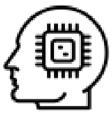
Chip Foundries

- Predevelopment of technology modules
- Access to design services to create foundry business
- Outsourcing Handling of prototype runs / small volume business



IDMs (Integrated Device Manufacturer)

- R&D services, focus on transferability into commercial production lines
- Use of Advanced heterogenous system integration for creating new products and business offerings
- Options for insourcing of high innovative products with volume forecast
- Design services for IDM's new chips



Semiconductor Customer

- Easy access to specialized technologies for high complexity products
- Use of Advanced heterogenous system integration for creating new products and business offerings
- Proof of Concept, Demonstrators with high TRL / low volume production,
- Scale up into commercial technologies commensurate with market growth

Research Community

- Access to extended technology capabilities in research cooperation
- Support of transfer of research results into applications

Start-ups

- Access to special technology
- Prospect to create technology start-up without own cleanroom

Profile of Fraunhofer in Microelectronics Value Chain

Research Fab Microelectronics Germany (FMD) is the world's leading **research association** for micro- and nanoelectronics applications and systems. 15 institutes from the two research organizations, Fraunhofer and Leibniz, have combined their expertise, thus creating a new quality to the research and development of micro- and nano-systems. It offers new technologies and cross-technology solutions up to a **high technical readiness level** from a single source for partners in industry and science. As a global driver of innovation and the largest cross-location R&D alliance for microelectronics in Europe, FMD offers a unique diversity of expertise and infrastructure. It bridges the gap between basic research and **customer-specific product development.** With its member institutes, the FMD demonstrates research achievements of international excellence. In this way, it contributes to take Germany and Europe into a leading position in research and development. Based on the scientific excellence of its institutes, FMD continuously develops its technological portfolio and translates it into innovations - for the benefit of society and to strengthen the German and European economy.

What does Fraunhofer FMD do?

- FMD provides impulses for developments and system solutions in the high-tech sector, cooperates with international partners and actively shapes the German and European research agenda.
- FMD bundles its resources across the entire value chain of micro- and nanoelectronics to maintain technological sovereignty in Europe and to strengthen Germany's competitiveness as a business location.
- FMD enables comprehensive and easy access to new applications of micro- and nanoelectronics at different technical levels of maturity and offers complete solutions from a single source.
- FMD lowers the entry threshold into future-oriented high technologies for all users of microelectronics in industry and science and is an important innovation partner also for small and medium-sized enterprises.
- FMD offers training and further education opportunities for future careers in microelectronics and supports the transfer of knowledge by brains.
- FMD supports start-ups in high technologies - The "FMD Space" offers start-ups direct access to Europe's largest machine park in the field of nano- and microelectronics.

FMD in numbers

- *5400 employees, including 2800 researchers*
- *15 innovative research institutes*
- *13 cleanrooms with 2200 devices on a total of more than 19500 sq.m space*
  - *More than 10 million moves per year*
  - *Wafer-sizes from 2" to 300 mm*
  - *≤ 200 mm CMOS and MEMS Line, 200 mm Si Line, 150 mm SiC Line, 200 mm (Bi)CMOS Line, 100 - 300 mm Packaging Line, 300 mm Screening FAB*
  - *Semiconductor materials from Si over SiGe to Compound Semiconductors like SiC, GaN, GaAs, InP processing up to 4".*

Members of FMD

- Fraunhofer Institute for Applied and Integrated Security (AISEC)
- Fraunhofer Institute for Electronic Microsystems and Solid State Technologies (EMFT)
- Fraunhofer Institute for Electronic Nano Systems (ENAS)
- Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR)
- Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, (HHI)
- Fraunhofer Institute for Applied Solid State Physics (IAF)
- Fraunhofer Institute for Integrated Circuits (IIS)
- Fraunhofer Institute for Integrated Systems and Device Technology (IISB)
- Fraunhofer Institute for Microelectronic Circuits and Systems (IMS)
- Fraunhofer Institute for Microstructure of Materials and Systems (IMWS)
- Fraunhofer Institute for Photonic Microsystems (IPMS)
- Fraunhofer Institute for Silicon Technology (ISIT)
- Fraunhofer Institute for Reliability and Microintegration (IZM)
- Leibniz Institute for High Performance Microelectronics (IHP)
- Ferdinand-Braun-Institut, Leibniz-Institute of High Frequency Technology (FBH)

*Founded in 1949, the **Fraunhofer-Gesellschaft** based in Germany is the world's leading applied research organization, specializing in contract-based R&D services and development of technologies, processes and products from proof-of-concept to market readiness. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, it is helping shape our society and our future. Fraunhofer works with an annual research budget of €3.6 billion with 75 institutes across Germany and over 32000 employees worldwide. Fraunhofer generates €3.1 billion of this from contract research. Our global footprint is very strong, with offices and research centres in the USA, Europe and Asia. Some of our renowned innovations are the MP3 software, white LED's and the smallest of cameras. Fraunhofer has been a long-time trusted innovation partner in India, collaborating with some of the major players in the fields of Material Science, Energy, Environment, Automotive, Electro-mobility, Production Technology, Microelectronics and Smart Cities, working with Industry, Government and Public Sector.*

Credits:

- *Ms. Anandi Iyer, Director, Fraunhofer Office India*
- *Mr. Aditya Fuke, Senior Manager – Strategic Projects, Smart Cites & IoT, Fraunhofer Office India*
- *Mr. Nilesh Raghavan, Data Analyst Intern, Fraunhofer Office India*

__Electronics, Products, Innovation, Consortium (EPIC)__ is a not-for-profit organization fuelled by a vision to build India into a Product Nation through Electronics. It was established to cultivate a comprehensive ecosystem covering design, manufacturing, and integration by leveraging India's vast potential. This effort is in sync with government initiatives and industry trends, focused on maximizing India's capabilities, fostering growth, and driving innovation.

Credits:

- *Dr. Ajai Chowdhry, Chairman, EPIC Foundation India; Co-founder, HCL*
- *Mr. Ish Kumar Bhargava, Executive Director, EPIC Foundation India*

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