INSIGHTS

SYNERGIA FOUNDATION

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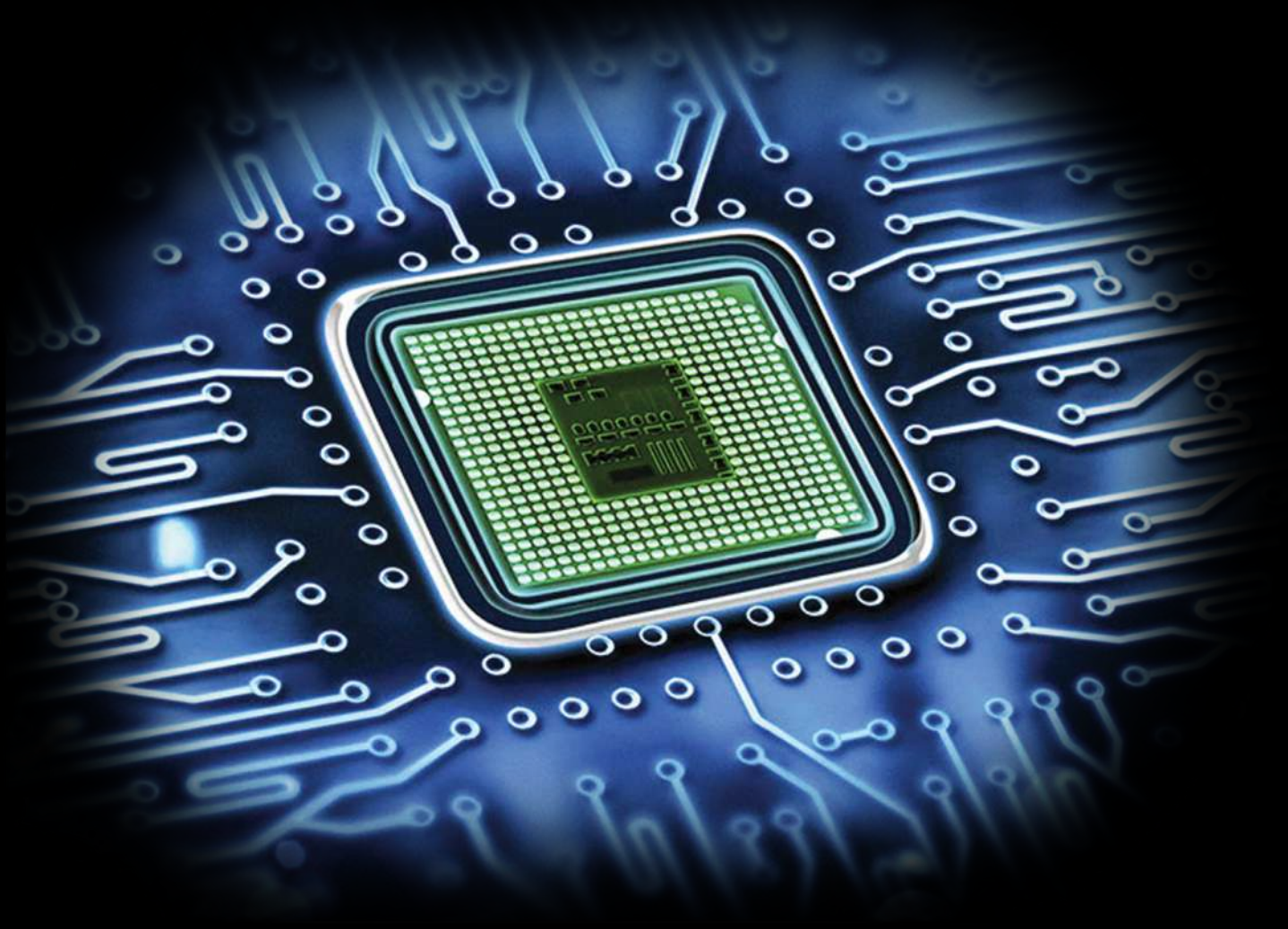

SEMICONDUCTORS: THE FAB FUTURE

IMPACT BEYOND BORDERS

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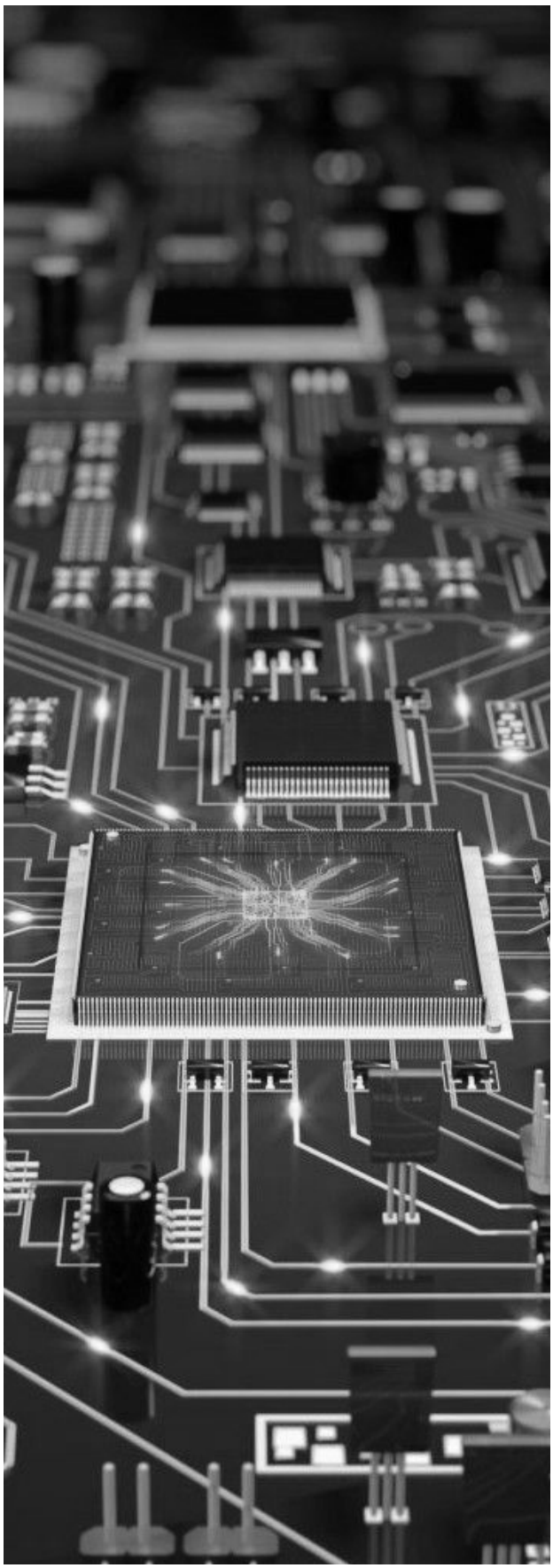

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AR. NO. 01

A GLIMPSE OF THE FUTURE

Semiconductors are the key to an imminent Fourth Industrial Revolution, with 5G wireless and AI transforming the societal, economic and security verticals

Dr. Arogyaswami Paulraj, is an Emeritus Professor at Stanford University and winner of the Marconi Prize in 2014. He is the inventor and pioneer of the Multiple Input Multiple Output (MIMO) wireless, the key technology behind 4G/5G mobile and Wi-Fi networks. He has been associated with the Synergia Foundation for many years.

Semiconductor technology touches almost every aspect of our lives – from smartphones and the internet to automobiles, commercial jets, medical imaging and satellite sensing. It has powered the Information Technology sector (IT), thereby ushering in the Third Industrial Revolution that we have been experiencing in recent decades. Once again, semiconductors will be key to the imminent Fourth Industrial Revolution, with 5G wireless and AI transforming the societal, economic and security verticals. It will also revolutionise new sectors like intelligent transportation, energy, manufacturing, and agriculture. Semiconductor technology began with the invention of the transistor at the Bell Labs in 1947. The industry was first seeded in the Silicon Valley in the 1970s, with Fairchild Semiconductor and Intel being the major pioneers. The industry is now spread across the globe, with the U.S., China, Taiwan, South Korea, and Japan emerging as the primary participants. Semiconductor devices handle data in binary form (bits) and can both store and manipulate them via arithmetic and logical operations. The chips execute billions of instructions per second, enabling them to run everything from smartphones to commercial jets. The industry has, till recently, witnessed consistent price-performance improvements known as the Moore's Law, named after Gordon Moore at Intel, who observed the trend in the 1970-80s. Nearly five decades since the industry began, the price-performance has improved by a staggering ten million, making semiconductors both ubiquitous and powerful.

THE SPREADING WEB OF FABS

The semiconductor industry was initially a U.S. monopoly, with companies like Intel designing and manufacturing (fabricated) their own chips. By the mid-1970s, however, Japan overtook the U.S. in the semiconductor memory market. By the 1980s, a semiconductor fabrication plant (fab) cost about 150 million USD, and only very large companies could afford to set up captive fab lines. In the late 1980s, a new business model pioneered by the Taiwan Semiconductor Manufacturing Company (TSMC) enabled a so-called fabless semiconductor model, whereby design companies could get the chips manufactured at a shared fab facility. This triggered the proliferation of fabless semiconductor companies. Qualcomm and Broadcom are good examples of the fabless model, starting small but growing into global giants. By 2000, the fabless model spread around the world, including the U.S., Europe, South Korea, Japan, China, and Israel. A fabless semiconductor company could often reach profitability with less than 100 million USD of venture funding. The fabs had meanwhile become more expensive and needed over a billion USD to build. The rising cost of fabs was due to the use of a smaller feature size (line width), which in 2000 was around 180 nanometres (nm). Today, twenty years later, the semiconductor industry is undergoing rapid changes again. On the fabless end, semiconductor chips with over

20 billion gates are routine and complex to design. They require 200-800 million USD to develop and sell into high volume markets like smartphones. This makes it difficult for fabless start-ups to compete and therefore, attract venture funding. The cost of fabs have also risen and now stands at around 19 -20 billion USD for the most advanced 5nm technology (node). Advanced nodes need highly skilled fab engineers, with skills often nurtured over many decades. Of course, they also need complex and expensive fab equipment like Extreme-UV lithography. As a result, many established fabs could not deliver on 5nm or even 7nm nodes, triggering major restructuring of the industry. Apart from being a critical industry, semiconductors are now the most technologically advanced sector for any country. Most of the chips produced today use the 12-28nm nodes, with 5nm reserved for the most challenging applications like high-end smartphones. The latter constitutes only about 5% of the total market share. The industry is also extremely competitive.

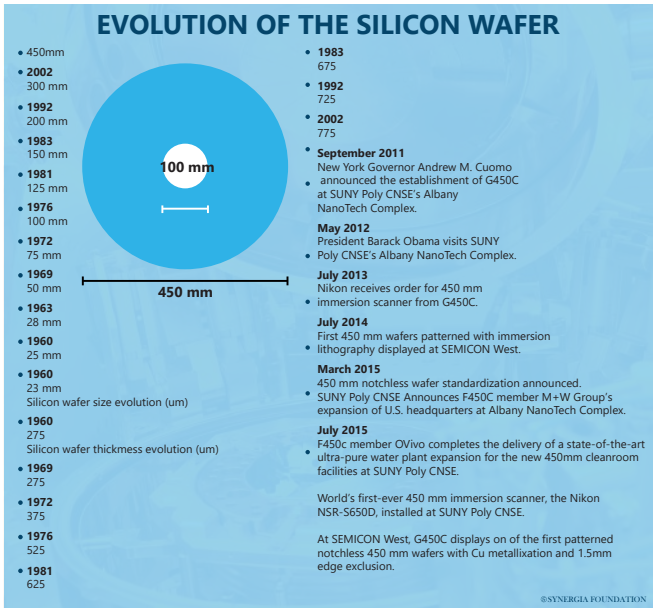
> “Fab lines, built with huge investments, are often kept running at full capacity to maintain profitability, but this also creates major pricing challenges in a market with fluctuating demand.”

THE ARENA FOR GLOBAL COMPETITION

The semiconductor industry now commands about 500 billion USD of annual revenue. The U.S. and China are the biggest consumers of these chips. The industry is highly international; a smartphone chip may have seen value addition, both in design and in manufacturing, across 20 companies and six countries. In the fabless segment, U.S. companies (Broadcom, Qualcomm, Nvidia,) still lead in computer and application-specific chips, while South Korea leads in memory chips. In the fab segment, Taiwan, South Korea, U.S., and Japan lead in the frontend technology (lithography and deposition), and China, South Korea, and Taiwan in the backend (assembly and test). U.S. has largely lost its pre-eminence in semiconductor fabrication. Other segments of this industry include the design tools (EDA), where the U.S. is still dominant, and equipment for fabs where the U.S., Europe, and Japan are the leaders. Given the growing market for semiconductors with the advent of 5G, the race for technology leadership is no surprise. A total of three trillion USD of global R&D and Fab investments are expected over the next ten years. TSMC and Samsung have each announced 250 billion USD of investments over the next decade. China had invested over 100 billion USD in the past decade and will likely add another 1.4 trillion USD in the coming decade. The U.S. Govt. is also expected to invest about 50 billion USD to shore up declining fab capability in the country. With rising tensions between the U.S. and China in technology, the latter's status in semiconductors attracts global interest. China has about around 100 fabless companies (e.g., HiSilicon, Tsinghua UniGroup), but still lags behind the U.S. leadership in this segment. China also has about 20 fabs that operate 70 nm to 12 nm nodes. Most of them are headquartered in the country like the Semiconductor Manufacturing International Corporation (SMIC), but TSMC and Samsung also operate fabs in the country. China is particularly strong in the backend fab segment but lags behind Taiwan and South Korea in the frontend. It had planned to deploy the top line 5nm node that requires special fab equipment, sourced from the U.S., Europe, and Japan. However, the U.S. Govt. has now blocked sales of this equipment to China. Looking to the future, China does have companies in every segment of the fab industry, but they are probably two to five years behind the current world leaders. More than massive capital investments, which China can pump in, the key to success in this industry also lies in Science and Technology (S&T) skills and experience, and this does take time to build. Semiconductor capability enjoys the highest national priority for technology in China and has full support from the highest political levels.

THE INDIAN SCENE

As far as India is concerned, it currently has no real share in the semiconductor industry. Consequently, every semiconductor chip, whether used in civilian or in military applications, is imported. India does host offshore research and development (R&D) operations for foreign fabless companies but has negligible fabless industry capability headquartered in India. In semiconductor fabrication, India had started early (and ahead of China) with the setting up of Semiconductor Corporation Ltd. (SCL) in 1983. SCL showed early promise but could not advance beyond the 800nm node and was simply unable to compete with the global industry. In 2006, it was renamed the Semiconductor Lab and absorbed by India's space program. India clearly has the need and the potential to become a major player in the global semiconductor industry, but many attempts over the past several decades have been unsuccessful. The highest levels of the Indian government are aware of the country's vulnerable position in this most foundational and strategic industry. Going forward, it is important to deploy new and innovative strategies to address these vulnerabilities.



AR. NO. 02

HOLDING ALL THE CARDS

With China's overwhelming domination of strategic supply chains, potential disruptions to the electronics industry looms large

Mary Kavita Dominic, is a Policy Research Associate with the Synergia Foundation. She has completed her masters in law and South Asian studies from the University of Oxford, UK.

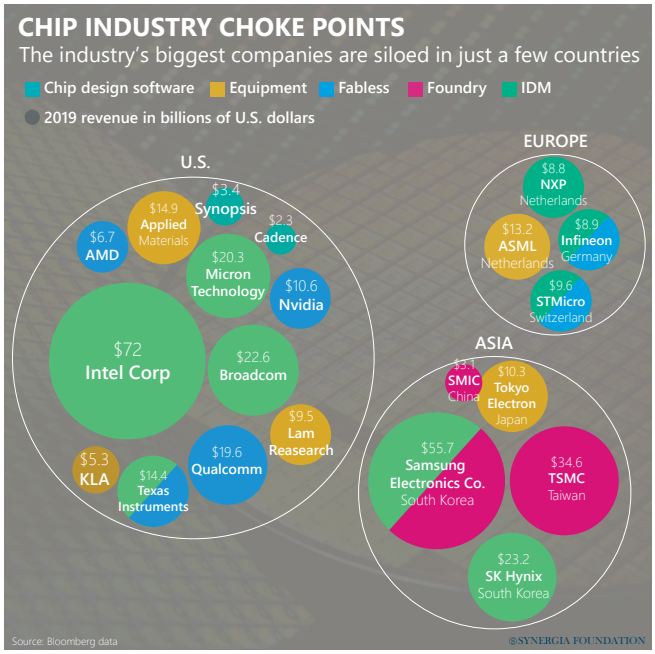
As the world continues to reel from a dearth of semiconductors, it has become extremely vital to secure supply chains from geopolitical risks and natural disasters. While the Covid-19 pandemic may have exacerbated the demand-supply imbalance in chips, the signs of an impending crisis had appeared long before the pandemic. Apart from negative variables like the U.S.-China trade war, the concentration of advanced manufacturing capabilities in the hands of a few players had significantly constricted the entire value chain. To build resilience in the future, it will be important to identify and mitigate potential disruptions to the semiconductor industry. More broadly, there is a pressing need to look beyond microchips and anticipate threat factors for the electronics industry and other allied sectors.

CHOKEPOINTS

Currently, the semiconductor supply chain is dominated by a few countries, which by itself is a risky proposition. The 2019 Japan-Korea trade war that affected the supply of semiconductor chemicals, was a precursor to this crisis. Similarly, the concentration of foundry capacity in a few companies like Samsung and the Taiwan Semiconductor Manufacturing Company (TSMC) represents a potential bottleneck. Meanwhile, the Netherlands-based ASML Holding enjoys a virtual monopoly on advanced photolithography equipment, which is used to print chips onto a semiconductor substrate. Similarly, American companies like Synopsis and Cadence Design Systems reign supreme in electronic design automation software. Unless these existing supply chains are diversified across multiple players, they will remain vulnerable to single-point failures. Acknowledging this, industries around the world have urged their respective governments to build capacity in strategic sectors like semiconductor chips, photovoltaic cells, and lithium-ion batteries. Owing to their sophisticated nature, however, this will not happen overnight. It will require substantial planning and investment, apart from a well-coordinated rollout. In the meantime, identifying potential disruptors and evolving mitigating strategies can be the first step in countering supply chain bottlenecks.

THE SILICON SQUEEZE

Silicon is an integral part of several electronic applications, including integrated circuits or microchips. This metallically lustrous metalloid element is used to manufacture wafers that are eventually deployed in smartphones, notebooks, desktops, industrial products and other electronic equipment. Currently, China dominates the supply of silicon, with a production volume estimated at 5.4 million metric tons in 2020. The Xinjiang-based Hoshine Silicon Industry and its subsidiaries are the world's largest producer of silicon metal. There is also intense competition among various silicon production zones in the country, which is actively encouraged by the government to amplify the national output of this strategic metal. As the global demand for wafers escalates at an unprecedented rate, China's pre-eminence in silicon production puts it in a strategically enviable position. It can stockpile essential



raw materials for its own semiconductor industry, putting international manufacturers at a significant disadvantage. Supplies can also be squeezed at an opportune moment to extract geostrategic concessions. During the Trump Presidency, the U.S. had finally woken up to this threat. It promptly imposed tariffs on silicon and other raw materials imported from China to encourage domestic production. More recently, the Biden administration banned silica-based products from the Hoshine Silicon Industry. Although this was officially justified as a measure to counter the use of forced labour practices by the company, it had the added advantage of discouraging American companies from relying on raw material sources in China. Such incidents hold a valuable lesson for India, as it aspires to build commercial fab capacity in the future. To ensure robust supply chains, the country will need to diversify its procurement of electronic-grade silicon.

THE SOLAR STRANGLEHOLD

Besides semiconductors, China's strategic hold over the supply of silicon can have implications for renewables, especially in the solar sector. As can be recalled, polycrystalline silicon is most commonly employed in the production of photovoltaic cells that convert solar energy into electricity. In fact, a report by the Sheffield Hallam University claims that 95 per cent of solar modules rely on polysilicon as their primary material. With 'net-zero' deadlines spurring the installation of solar panels globally, there will be a proportionate increase in the demand for such polysilicon. Here again, the Dragon has stolen a march on other countries by substantially investing in polysilicon research and production. Local governments have also wooed start-ups by offering free land and no-tax incentives. As a result, four of the world's five largest polysilicon manufacturers today are based in China, as per a study by the German firm Bernreuter Research. This near-singular dependence on China can render the solar industry vulnerable to supply chain bottlenecks and price variations. This was amply demonstrated in 2017, when polysilicon prices spiked by almost 35 per cent after environmental regulators shut down factories in China. Given that the country accounts for nearly 70% of the global production capacity today, similar disruptions can be expected in the future. Beijing also dominates other aspects of photovoltaic technology, including the supply of components. In this context, it is important for countries around the world to expand their sources of polysilicon and other raw materials, as they embark on their clean energy missions.

A BATTERY MONOPOLY

> "Building resilience in sectors like semiconductors or solar energy will have little meaning if energy storage devices are constrained by supply chain disruptions."

As industries and transport infrastructure transition to an 'electric future', batteries will play a critical role in their success. In this veritable milieu, lithium-ion (Li-ion) batteries have emerged as a primary power source for portable electronics. With global automakers rapidly adding electric vehicles to their portfolio, the demand for such lithium-ion batteries is expected to surge to as much as 5.9 terawatt-hours a year by 2030. Unsurprisingly, China has seized this momentum and established a commanding market lead over its competitors in the battery space. According to an analysis by Bloomberg NEF, it had dominated the lithium-ion battery supply chain in 2020. Apart from controlling 80 per cent of the world's raw material refining, it had 77 per cent of the world's cell capacity and 60 per cent of the world's component manufacturing. As far as raw materials are concerned, the country controls the processing of almost all critical minerals, whether it is lithium, cobalt, rare earth, or graphite. In fact, it produces more than 60 per cent of the world's graphite, allowing it to dictate world prices. Although the country does not have natural reserves of cobalt, it has secured exclusive access to mines in countries like the Democratic Republic of Congo (DRC). In fact, a working paper published by the Organisation for Economic Co-operation and Development (OECD) suggests that eight of the 14 largest cobalt mines in the DRC are owned by the Chinese, accounting for almost half of the country's output. Similarly, the country has bought stakes in mining operations across Australia and South America to supplement its own reserves of lithium.

Assessment

A chokehold over raw materials can be devastating in the long run, irrespective of the country wielding the power. When supply chains are disproportionately controlled by a single player, they are particularly vulnerable to geopolitical disruptions or acts of God. Worse, they can be used as a strategic leverage in times of conflicts or confrontations.

Given this reality, it is important to future-proof supply chains against the potential hoarding of raw materials by a few key actors.

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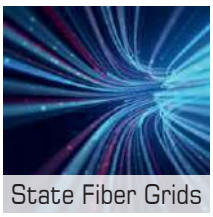

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AR. NO. 03

'FAB FUTURE' FOR INDIA

The semiconductor industry forms the foundation of technologies that drive economic growth, national security and critical infrastructure

Dr. C.S. Rao, is the Chairman and Co-Founder of QuadGen Wireless Solutions Inc. Previously, he was the Manging Director at Intel - South Asia and Middle East.

India's ambitious social objectives of universal education, health care, agriculture growth, booming commerce, and reliable and efficient banking, are all dependent on the '3-Cs'- Connectivity, Command and Control and Cloud Computing applications. To achieve this level of digitisation, which is unprecedented, the country will need to muster the power of silicon. Currently, the era of digital transformation is being driven through several government initiatives - Digital India, Skill India, Smart City India, Make in India etc. The investment in all these sectors must be aligned to build the 'Fab of Future' for India. This is a compelling necessity, if India has to exploit the growth potential of consumer electronics, mobile communication, connected electric grids, connected smart enterprise networks and industrial automation-driven smart manufacturing.

Over the next few years, next-generation technologies will revolutionise the way we do business. Apart from 5G, technologies like Wi-Fi 6, Multi-access Edge Computing (MEC) and Cloud Computing will be rolled out between 2021 and 2025. Moreover, Wi-Fi 7 and 6G are expected to become operational between 2025 to 2030. Connected vehicles, threat intelligence-based cybersecurity etc. are other promising demand drivers for the massive scale of 6 -10 B endpoint devices in India that require Very Large Scale Integrated (VLSI)-based chips.

DEMAND EXCEEDING SUPPLY

The global chip shortage is posing a serious threat to societal welfare, akin to the COVID-19 pandemic witnessed over the last few months.

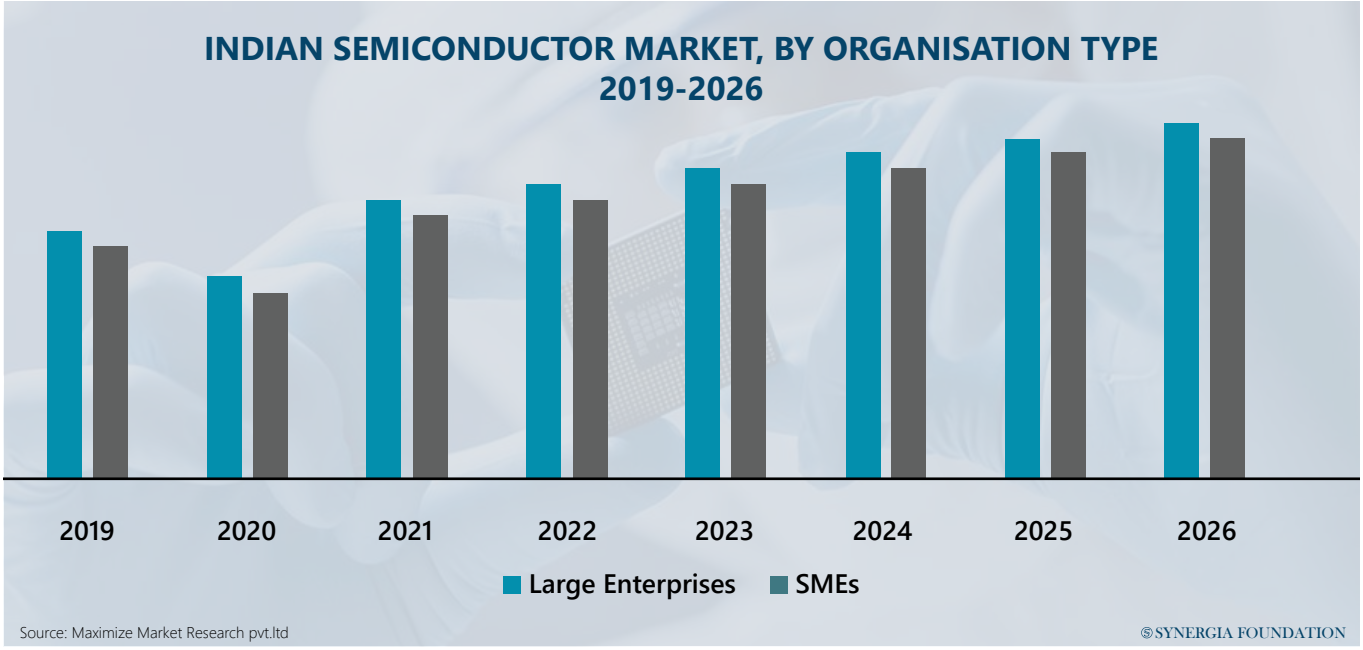
> "The level of electronic goods imports by India makes a compelling business case for establishing fab facilities in the country."

Other countries have already recognised this and have taken the lead. The U.S. has committed $ 50 billion federal investment through the United States Innovation and Competition Act (USICA) for semiconductor manufacturing, research and design initiatives. Along similar lines, China, South Korea, and the EU have earmarked up to $250 billion as government investment over the next decade, for the growth of the semiconductor industry segment.

Furthermore, nineteen new fabs will be operating by the end of 2021, and another ten will join by 2022. The fab industry is looking at an investment of over $140 billion to meet the accelerating demand of chips across the wide range of market segments, including 5G/Cloud/ MEC/ Industrial Internet of Things/ Health Care/Connected Vehicles/Security and Surveillance. It is further predicted that the worldwide integrated circuit (IC) market would top $500 billion in 2021.

INDIA'S OPTIONS

The global chip shortage is posing a serious threat to societal welfare, akin to the COVID Over the last three



decades, despite many inter-departmental confabulations, there has been very little progress in establishing a fab industry in India. Therefore, the government must reassess the situation across the entire semiconductor value chain and act to roll out a new 'Fab of Future' policy. India cannot afford to lose any more time in the creation of a long-lasting industry base for semiconductor manufacturing in the country.

By 2023, India must establish a fab facility of 200 mm wafer production to meet the demand patterns in consumer electronics, mobile communication and the information technology (IT) segments industry with cloud architecture-based data centre growth. Indian silicon domain specialists estimate that there is a need for about 100K wafers per month of 200 mm equivalents.

Establishing a fab over the next two years will surely ensure a kind of economic security for India in digital sectors by 2024. Indian fab facility creation has to start from the 20nm level and should have the capability to handle up to 7nm in the next four years. The investment for such a 200 mm greenfield fab will cost at least US $2 billion and take approximately 18 months to establish and start production. In this regard, India may consider the provision of funding along the lines of the U.S. Chip Act. To incentivise fab manufacturing and research, there is also a need for semiconductor investment tax credit. A model already exists in the 'Facilitating American Built Semiconductors Act (FABS)' in the U.S., which is a bipartisan legislation. India must guard against global semiconductor supply chain vulnerabilities, as geopolitical tensions involving China, Taiwan, Israel and the U.S. could lead to export restrictions of silicon ICs. A homegrown fab would ensure that India has safeguards against a potential unilateral threat in silicon supplies. India has to evolve its own unique model, drawing on hitherto established frameworks in the U.S. and China.

HOMEGROWN TALENT

India has a proven and experienced talent pool in application-specific integrated circuit (ASIC) design, validation, reference circuit design service, electronic design automation (EDA), storage technology such as DRAM and NAND, real-time embedded design as well as physical computer-aided design (CAD) methodology.

It also has expertise and exposure in AL-ML based techniques and tools that can drive the automation level required to scale up the digital chip design complexity. The industry promises a significant spurt in job opportunities with a proven job multiplier factor of 6 - every job in the semiconductor industry enables the creation of five more jobs.

The jobs could be in the range of 60K to 80 K for design, verification, validation, testing etc. and an additional 100 K for other related jobs. It is estimated that in the U.S., a federal investment of $50 billion will have a 4x multiplier effect on the U.S. economy over the next five years.

STATE-OF-THE-ART TRENDS

The industrial growth in central processing units (CPU) and graphics processing units (GPU) is currently at 30 per cent year-on-year. Meanwhile, the Super Computing/High-Performance Computing (HPC) is at 50 per cent year-on-year, which will further drive the growth in CPU/GPU and NAND storage. Moreover, the internet exchange traffic has reached a world record of 9 TBps at Frankfurt.

This trend will further drive data center and CPU growth. Moore's law will continue for the next 5-7 years at the very least, with respect to CMOS transistor density of packing on substrates.

For 7nm nodes, the technology behind Moore's law continuation is Extreme Ultraviolet Lithography (EUV). The next revolution for 1 nm is High Numerical Aperture EUV (HNA_EUV). Front End of Line (FEOL) device architecture is another driver for Moore's law continuity. In this context, India needs to account for the lightning speed at which computing technology is advancing.

AR. NO. 04

GET THE CHIP ROLLING!

With demand far outstripping supply, the semiconductor industry is in flux, which holds great promise for an accelerated Indo-Taiwan collaboration in the field

Dr K.D Nayak, is the former Director-General of the Defence Research and Development Organisation (DRDO). This article is based on his views at the 104th virtual forum on 'Semiconductors and Supply Chains in Asia', jointly organised by the Synergia Foundation and the Taiwan Centre for Security Studies.

As India explores avenues for collaborating with the Taiwanese semiconductor industry, it is important to map its strengths and weaknesses in this critical field. At present, there are three fabrication units in the country.

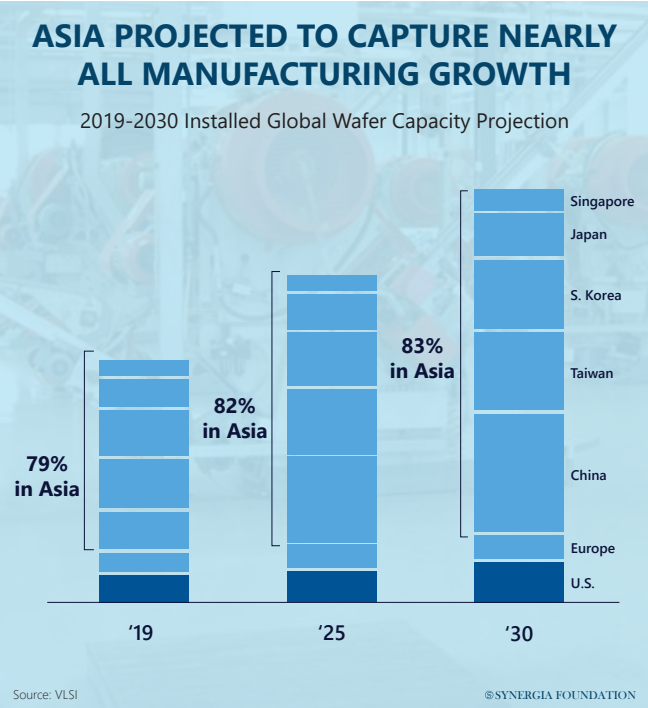
While the Semiconductor Complex Limited (SCL) in Chandigarh works on silicon technologies and application-specific integrated chips (ASIC), the Silicon Technology and Applied Research Centre (STAR-C) in Bangalore houses fabrication facilities for micro electromechanical systems (MEMS). Meanwhile, the Gallium Arsenide Enabling Technology Centre (GATEC) in Hyderabad focuses on compound semiconductor devices as well as related technologies and research.

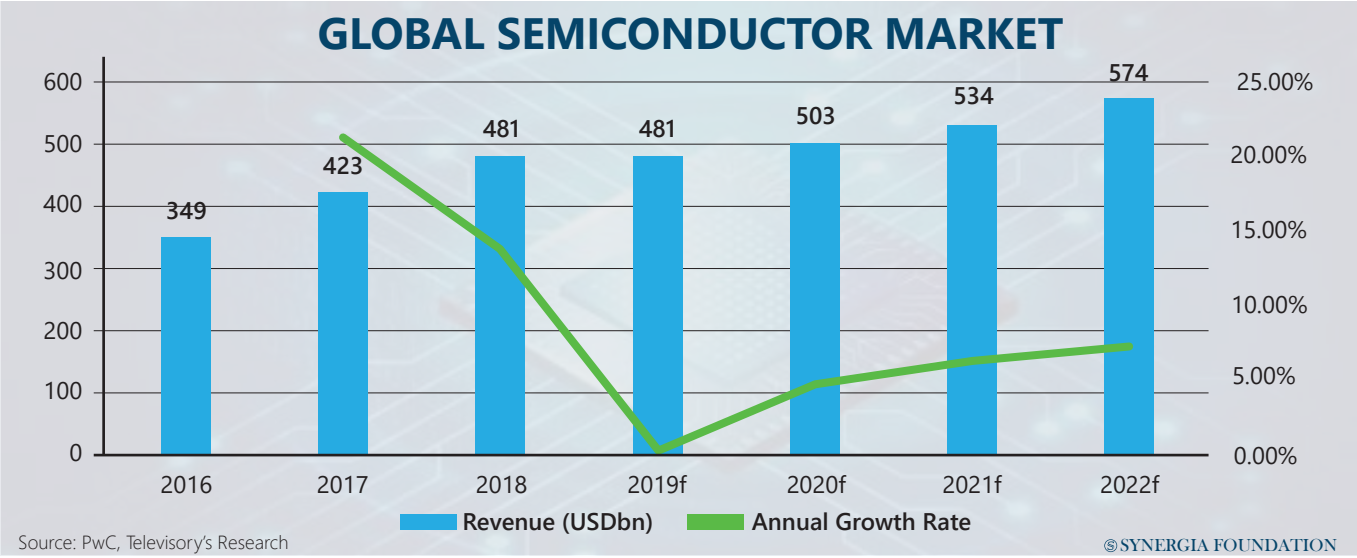
However, these facilities mainly cater to the requirements of the Indian Space Research Organisation (ISRO) and the Defence Research Development Organisation (DRDO). There is no state-of-the-art fab for high-end, commercial semiconductors. As a result, successive Indian governments have been attempting to incentivise companies into setting up fab units within the country.

A SWOT ANALYSIS

Over the past seventy years, electronics has functioned as the oil for industrial revolutions around the world. Its omnipotence has made it possible for industries and countries to grow exponentially. There are two key components to this field, namely hardware (Nar) and software (Nari).

As far as India is concerned, it has progressed well in the area of software, despite lacking core design. In hardware components and assembly, however, the country's





contribution has been extremely sub-critical. This is particularly true for the semiconductor industry. Unless India becomes self-sufficient in this sector, it will not be able to grow and make commercial gains.

Currently, India has a good ecosystem for chip design. Most multinational corporations like Intel, IBM etc., have their design houses here. In fact, the backend for the first 65nm chip was done in the country. Apart from such obvious advantages in Very Large-Scale Integration (VLSI) design, India is one of the fastest-growing internet economies. With more than 65 per cent of its population below the age of 35, the country has a digitally aspiring demography. This translates to a robust demand for semiconductors in India, with the market being valued at $410 billion by 2030.

In terms of manufacturing capacity, however, the Indian semiconductor industry has fallen behind. Apart from limitations in hardware and equipment maintenance, it has suffered from the intermittent availability of land, power, water etc. However, many of these concerns have now been addressed, with at least five sites readily available for manufacturing.

The government has also embraced proactive policies to attract fab units. For instance, it has announced a one-billion-dollar cash incentive for chip manufacturers that are willing to shift to India.

THE ROAD AHEAD

To foster manufacturing in semiconductor components, there are two streams that India needs to focus on – a) silicon-based technologies, which constitute about 80%-90% of the semiconductors manufactured today, and b) evolving compound semiconductor technologies like Gallium Arsenide, Gallium Nitride, Silicon Carbide etc.

In the Silicon segment, India can concentrate on the establishment of fabs that manufacture state-of-art nodes in the 14nm-28 nm scale. Currently, the country only has older technology nodes that cater to strategic needs. Since disruptions in the global supply chain have created problems for industries like automotive, telecom and electronics-dependent data centres, there is a pressing need to scale up hardware requirements. India should build a good ecosystem through governmental incentives and investments, as was done in the initial phase of its software industry development.

TAIWAN AS A PARTNER

Taipei can be a critical partner for New Delhi, given its strength in the semiconductor manufacturing industry. After all, the Taiwan Semiconductor Manufacturing Company (TSMC) alone accounts for nearly 56 per cent of the global market in semiconductors. It is also the pioneer in high-end technology fabs that manufacture 3nm chips.

> "Against this backdrop, there is a unique opportunity for India to combine its design capabilities with Taiwan's technological prowess."

As a tentative first step, the two countries can consider cooperating on 14-28nm chips. Another area for potential collaboration could be the setting up of Assembly, Testing, Marking, and Packaging (ATMP) businesses in India. Since there are many micro, small and medium enterprises in Taiwan that are engaged in the ATMP sector, it is important to ascertain whether they can contribute to the Indian semiconductor industry.

As far as leveraging India's design capacity is concerned, the key question is whether companies like TSMC or United Microelectronics Corporation (UMC) are willing to share their standard cell libraries with Indian start-ups. If they are, the fabrication of Indian designs can be undertaken in countries like Taiwan or Singapore. It is not necessary that the manufacturing is immediately shifted to India.

At a time when the semiconductor supply chain has been constrained by geopolitical risks, this is an opportune time for the two friendly nations to explore models of cooperation.

AR. NO. 05

REMOVING INVESTMENT BARRIERS

In the highly complex and cost-intensive semiconductors industry, the key to success lies in a robust ecosystem and regulatory environment

Dr. Dennis Hu , is the President of the Foundation for Commerce and Cultural Interchange in Taiwan. He is also the Director-General of International Cooperation at the Taipei Computer Association. This article is based on his views at the 104th virtual forum on 'Semiconductors and Supply Chains in Asia', jointly organised by the Synergia Foundation and the Taiwan Center for Security Studies.

The unexpected disruptions brought on by the Covid-19 pandemic have severely impacted semiconductor supply chains, but as the world slowly heads towards the first green shoots of normalcy, the future looks optimistic.

As an extension of the surprise cycle that began in 2020, the overall semiconductor market will record another strong year of growth. However, a supply shortage will continue to affect industries like automobiles that rely on old technology nodes throughout 2021.

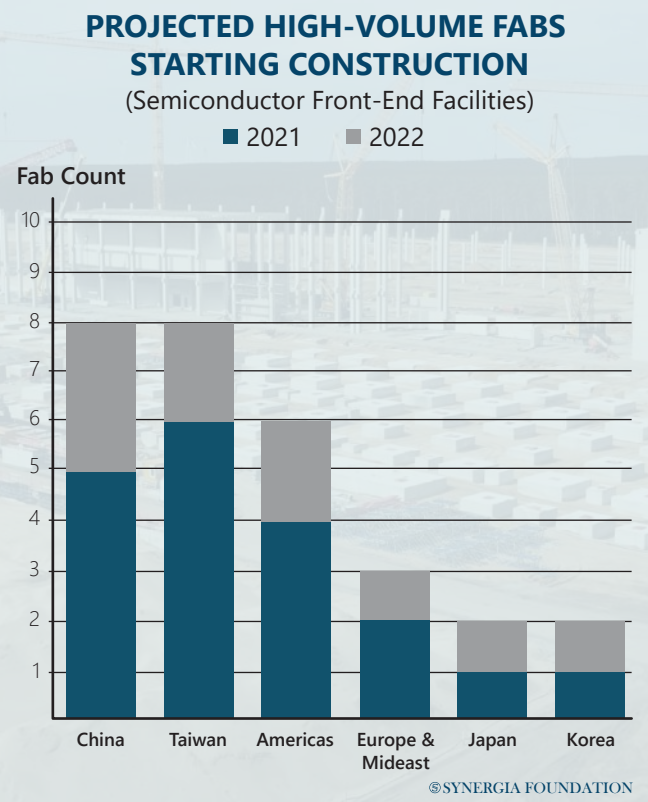
At present, some of the larger players like Samsung, Intel, and the Taiwan Semiconductor Manufacturing Company (TSMC) have collectively announced the investment of more than 130 billion dollars in new chip foundries. Taiwanese companies, in particular, are interested in the global development of semiconductor industries.

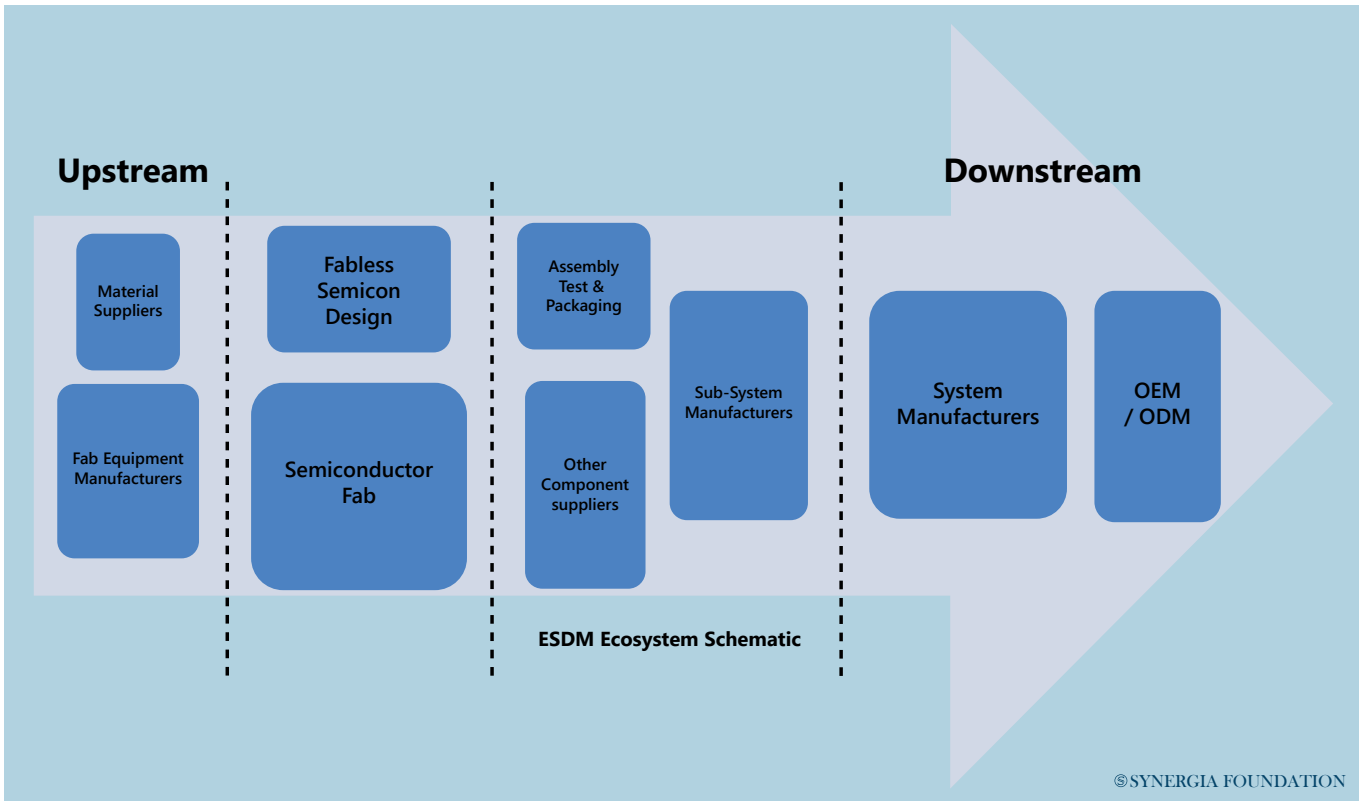
For instance, the TSMC plans to spend more than 100 billion dollars over the next few years in order to address capacity demand, with at least one foundry under construction in Arizona.

BUILDING THE RIGHT ECOSYSTEM

> "India has the attributes for a very promising market in the future."

Its production-linked incentive schemes are particularly lucrative for semiconductor companies. However, the important question to be addressed is how the country





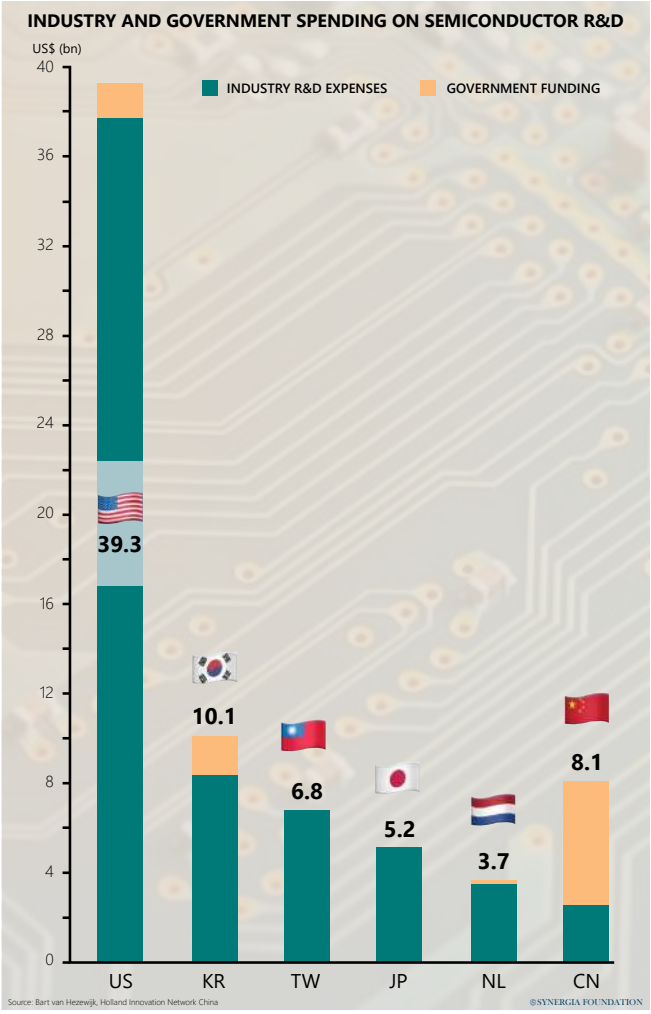
can be made attractive for potential investors. Given that the semiconductor industry is very sophisticated, there are certain factors that all chip companies will consider before shifting to new geographies, whether it is the U.S., Europe, or India. Apart from infrastructural requirements like electricity, water supply and land, skilled manpower is essential to the semiconductor industry. Other facilities like logistics or precision machinery, as well as supporting industries like petrochemical gas, are equally vital. Companies will also consider whether there is a competitive price in the targeted market. Finally, huge capex investments are integral to the success of the semiconductor industry.

By improving on these aspects, India can convince semiconductor industries in Taiwan, the U.S., South Korea etc., to diversify their investments in the country. Owing to its large market and strengths in Very Large Scale Integrated (VLSI) design, its ecosystem for chip manufacturing shows potential.

INDO-TAIWAN COOPERATION

Over the past decade, there has been a considerable collaboration between New Delhi and Taipei, especially in information and communications technology (ICT). In fact, Taiwanese companies like Acer, Wistron, Foxconn and Pegatron have actively invested in India. However, as far as the semiconductor industry is concerned, the two countries will have to work together in resolving some of the barriers that constrain the ecosystem. The Indian government, in particular, will have to address concerns about policy consistency and regulatory transparency in the country.

For now, it is not strictly necessary to commence cooperation in fabs or foundries. There are other elements of the semiconductor supply chain that can serve as a starting point, ranging from the design of integrated circuits to assembly, testing, marking, and packaging (ATMP). The Taiwanese Foundation for Commerce & Culture Interchange (FCCI) will play an active role in facilitating communication between industries in India and Taiwan.



AR. NO. 06

ONE STEP AT A TIME

India can leverage its existing strengths in design to establish a fabless ecosystem

Mr. Rajeev Khushu , is the Chairman of the Board of Directors at India Electronics and Semiconductor Association (IESA). He is also the Director of Corporate Affairs and Government Relations at Texas Instruments.

India has a good ecosystem for semiconductor design. Today, more than 30 per cent of the global design in chips is carried out in this country. In fact, companies like Texas Instruments (TI) have had their presence here since 1985.

There is hardly any semiconductor device that TI produces or manufactures which does not pass through India. In many cases, even the product definition happens in Bangalore.

Given this apparent strength in design, it will be relatively easy for India to step up its presence in the semiconductor supply chain. There is also great potential for inhouse consumption, owing to its large markets.

Fabless Ecosystem

Today, China has more than 50-60 fabless companies in the semiconductor domain. This can be attributed to the large amounts of money pumped into this sector by the government. In fact, even before the Covid-19 pandemic, President Xi Jinping had announced that the government would spend an excess of 400 billion dollars in the semiconductor industry.

Recognising the need for such proactive action, the Government of Karnataka has recently developed the Semiconductor Fabless Accelerator Lab (SAFL). This initiative seeks to develop and enhance the fabless ecosystem in Bangalore. Reports suggest that many fabless companies have already emerged out of this project. Owing to this success, the Union government is contemplating similar programmes at the pan-India level. To sum up,

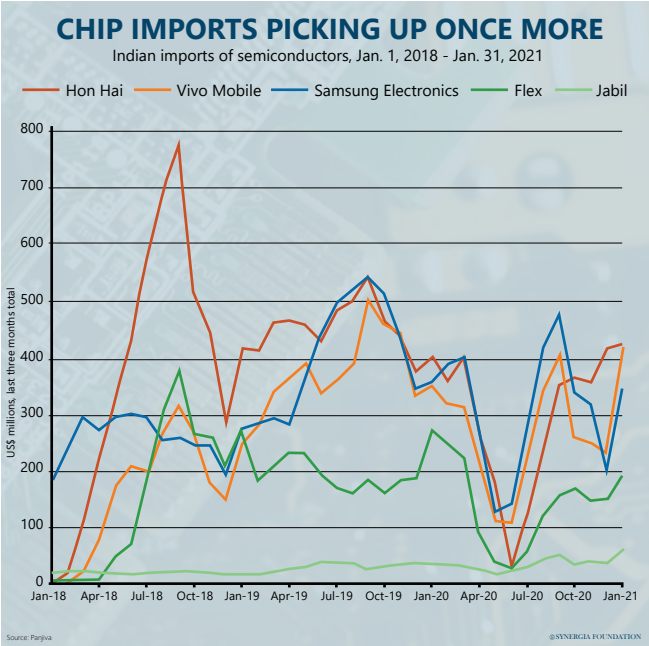
> "India needs to leverage its strengths in design and direct more funding towards the fabless ecosystem."

FOSTERING ATMP FACILITIES

Apart from establishing a fabless ecosystem, the next low-hanging fruit for India would be an Outsourced Semiconductor Assembly and Test (OSAT) or an Assembly, Testing, Marking and Packaging (ATMP) facility. Although countries like Malaysia and Philippines have already taken the lead in this sector, there are critical opportunities that

> "If redundancies are not built into the semiconductor supply chain, we are in for more rude shocks. The India Electronics and Semiconductor Association (IESA) is absolutely committed in working with the Taiwanese industry to future-proof supply chains."

Sandeep Aurora
Vice President - Business Development & Govt Affairs, IESA



India can capitalise upon.

Over the last year, semiconductors have witnessed an unprecedented surge in demand. In 2020 alone, the industry grew at 8-10 percent. For 2021, the preliminary figures indicate that the growth will be in double digits. With such an escalation in demand, there will be a concomitant increase in the requirement for fabs. This, in turn, can drive up the demand for OSATs and ATMPs, representing a significant entry-point for India.

JOINING THE VALUE CHAIN

Currently, Taiwan and other semiconductor majors are moving up the value chain by producing technology nodes below 7nm. Even as they upgrade to a niche fab, there are other countries around the world like India, which continue to have a market for less-advanced chips, particularly in the analogue domain. If these old technology facilities are incentivised to move to India, it will represent a win-win situation for both parties. Chips can be produced in a very cost-competitive and efficient manner.

Alternately, India can become a part of the global semiconductor supply chain, even before transitioning to high-end commercial fabs. In this regard, the India Electronics and Semiconductor Association (IESA) plans to release a white paper over the next couple of months. The paper will demonstrate how Indian companies in the automotive and pharmaceutical sectors can be incentivised to supply raw materials to fabs or OSAT vendors around the world. The IESA has also engaged in discussions with Orissa and other state governments to examine how rare earths and other minerals can be supplied to fulfil global fab and OSAT needs. After establishing its presence on the global value chain and building confidence among semiconductor fabs, India can ramp up its cooperation with chip manufacturers.

THE POLICY LANDSCAPE

Although India has been attempting to woo chip manufacturers for more than a decade, it has always been constrained by teething troubles. Having learnt from the past, the government has proactively sought to understand what the semiconductor companies require in order to shift to India. As far as the IESA is concerned, it is working closely with the Government of India to enable a robust policy environment. Apart from cooperating on Production-Linked Incentive (PLI) schemes, it has played an important role in calling for expressions of interest (EoI) from semiconductor fabs around the world. More than 20 companies have participated in this EoI process, with a sizeable number of speciality fabs displaying a keen interest in shifting to India. In this context, the future looks very promising.

AR. NO. 07

A GEOSTRATEGIC OUTLOOK

Supply chain resilience in the semiconductor industry is predicated on regional security within East Asia

Dr. Hon Min Yau , is a Professor at the National Defence University in Taiwan. This article is based on his views at the 104th virtual forum on 'Semiconductors and Supply Chains in Asia', jointly organised by the Synergia Foundation and the Taiwan Centre for Security Studies.

Amidst the rising tempo of the U.S.-China tech competition, Washington has banned the export of semiconductors manufactured under its propriety rights to China. This has resulted in a disruption in the industry, with worldwide attention being focussed on the evolving situation. After all, microchips and integrated circuits find applications in almost every aspect of human activity, ranging from cars and refrigerators to solar panels and toys. Although most semiconductor technology originates in the U.S., Taiwan is a dominant player in chip fabrication. It also hosts more than 60 per cent of fabless manufacturing facilities.

A COMPLEX ECOSYSTEM

The creation of microchips is not an easy endeavour, as it is capital heavy and technology-intensive. Semiconductor manufacturing is also contingent on a whole range of supporting activities. Apart from actual fabrication, the process relies on silicon materials, packaging, testing, supporting equipment and gas requirements through the entire supply chain. Over the years, semiconductor companies have also used nanotechnology to place more

SEMICONDUCTOR SHORTAGE: A PERFECT STORM

In the span of less than a year, there have been multiple supply chain disruptions and natural events that have lead to the semiconductor shortage we're experiencing today.

AUTOMOTIVE SECTOR DEMAND

The pandemic caused a drop in vehicle sales in spring 2020, which led automakers to cut their orders of all parts including electronics. In the third quarter, demand rebounded at an unexpected higher rate, but component supply was already committed to consumer electronics and IT equipment.

GEOPOLITICAL FACTORS

The former administration tightened regulations on sales of seniconductors to Chinese companies, resulting in those companies stockpiling chips. At the same time, American firms were cut off from chips when the federal government blacklisted a large Chinese manufacturer.

JAPANESE FACTORY FIRES

In July 2020, a fire at a Japanese factory cut off supplies of special fiberglass used in PCBs. Then in October 2020, another fire at a Japanese plant took advanced sensing devices used in automotive and other industries out of circulation. Most recently in March 2021, yet another factory fire has halted production for at least another month.

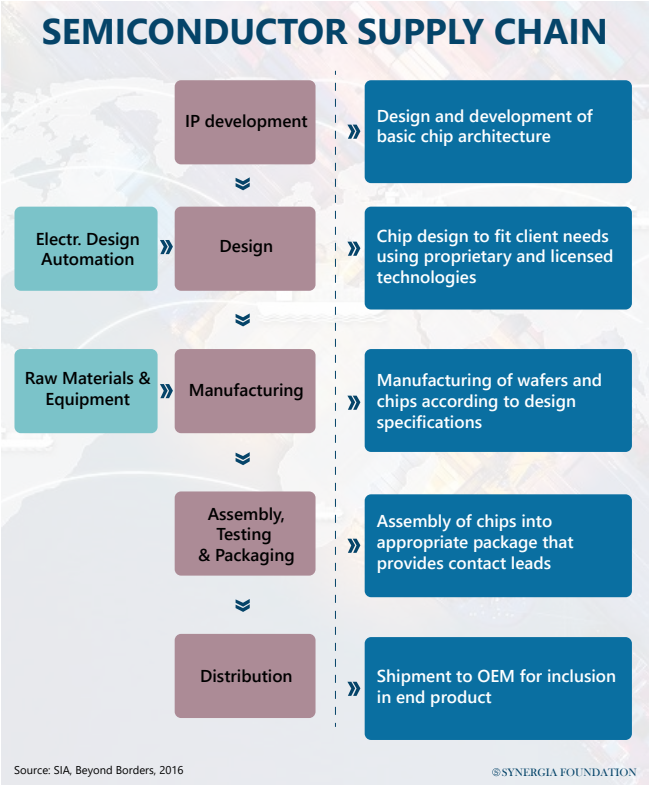
GLOBAL TRANSPORTATION CONSTRAINTS

In Q1 2021, nearly 7% of ocean freight remains in China ports in due to a shortage of shipping containers. Airfreight is in high demand to ship the vaccine, yet capacity has been reduced by 25% since there are fewer passenger planes available to carry freight. Recent grounding of Boeing 777 fleet with Pratt & Whitney engines has further exacerbated contraints.

TEXAS POWER OUTAGE

Exceptional cold weather and winter storm impacted much of southern part of the US causing a widespread power outages specifically in Texas. Austin Energy power grid asked its largest consumers, such as Samsung Foundry and other makers of semiconductors, to temporarily shut down their fabs. While it is possible to briefly turn off chip production, it is very difficult to restart. In fact, they have yet to resume normal operations as of early March.

Source: Harvard Business Review



complicated electronic circuits in a given space. In fact, Taiwanese firms have recently developed 3nm technology nodes that can be deployed in high-end smart devices with powerful computational abilities. This is increasingly sought after by companies like Intel and Apple. Finally, business feasibility, technology competitiveness and human talent are important factors for sustaining the semiconductor ecosystem.

PLAYING THE MAJOR LEAGUE

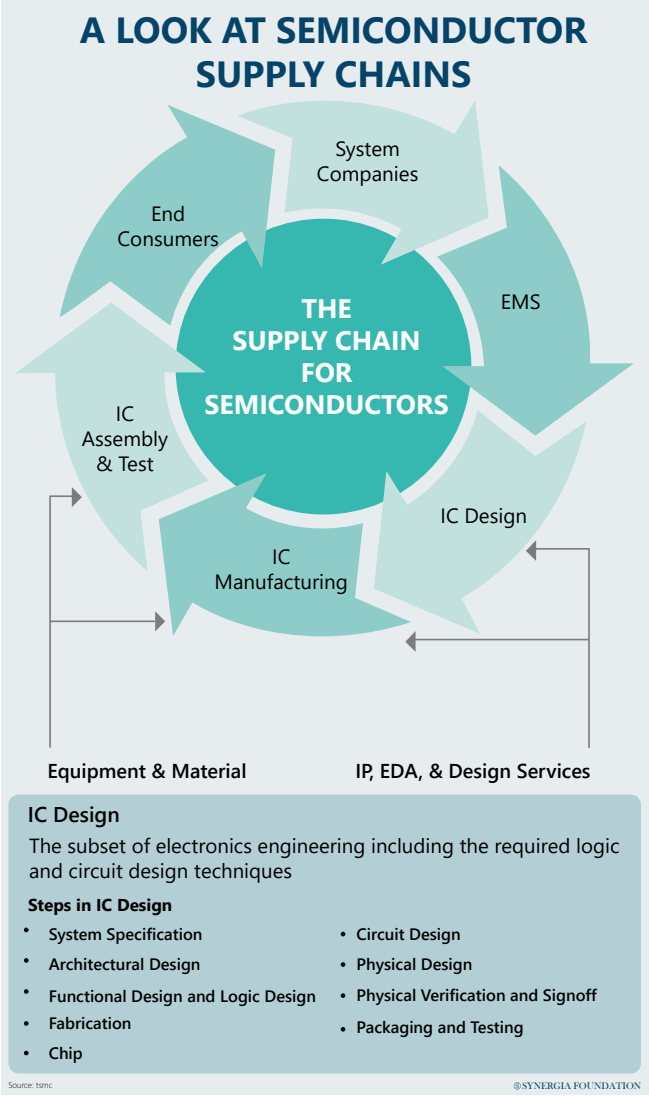
The growing competition in the semiconductor supply chain cannot be divested from its geopolitical context. Most of it is driven by a strategic powerplay between countries like the U.S. and China. Only recently, the Chinese Communist Party had passed its 14th Five-Year Plan, whereby it pledged to "adhere to the core position of innovation in China's overall modernisation, have Science and Technology (S&T) self-reliance and self-improvement act as strategic support for national development, and be oriented toward the world's cutting edge in S&T ". Beijing has also passed laws to resist U.S. sanctions in the semiconductor sector. Meanwhile, the Biden administration in the U.S. is unlikely to change the legacy of former President Donald Trump. It has not only persisted with sanctions on Chinese companies like Huawei but also enacted laws such as the U.S. Innovation and Competition Act to build a more resilient supply chain. This will be part of the larger 'Build Back Better World' initiative by G7 countries, which seeks to counter the strategic influence of Beijing.

WEB OF INTERCONNECTED NETWORKS

Information Technology (IT) systems were initially designed to facilitate interconnection. As a result, supply chains are today distributed across several intermingled networks. A typical semiconductor production process involves multiple countries, with products crossing national borders more than 70 times. This renders the entire supply chain fragile, with even the slightest disruption triggering far-reaching implications. Secondly, supporting industries like fabrication, testing, packaging etc., are mostly concentrated in the East Asian region. This status quo is unlikely to change over the next few years, as chip manufacturing and allied activities require highly specialised companies. Only a handful of firms can make high-quality and extremely compact microcomputer chips. Even if other countries substantially increase their investments in this area, it will take a long time for their technical expertise to evolve, along with the entire ecosystem.

> "Given this reality, it is important to protect the East Asian region from security and geopolitical risks that trigger supply chain bottlenecks."

As can be recalled, in 1996, Chinese missile drills in the Taiwanese Straits had triggered a panic, leading to a substantial rise in the price of computer components. To prevent similar incidents, the international community needs to pay more attention to regional stability in East Asia.



AR. NO. 08

AN EMERGING HUB

To emerge as an attractive destination for semiconductor fabs, India must incentivise indigenous design, harness human resources and leverage consumer markets

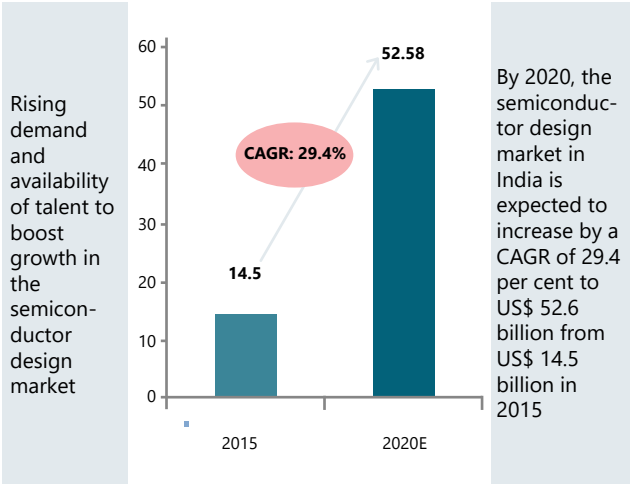
Dr. V Kamakoti , is a Professor at IIT Madras and a member of the National Security Advisory Board, Government of India. This article is based on his views at the 104th virtual forum on 'Semiconductors and Supply Chains in Asia', jointly organised by the Synergia Foundation and the Taiwan Center for Security Studies.

As the Covid-19 pandemic necessitates every company to diversify its supply chains and expand its product line, India can emerge as an attractive destination for semiconductor fabs.

> "With a growing consumer base in India, semiconductor manufacturing and packaging activities are likely to come closer to the market."

With the government's recent emphasis on 'Aatmanirbharta' or self-reliance, one can also expect more system-level designs and 'closeness to the product' in this country. In fact, India has already enacted policies to incentivise indigenous designs, owing to the national security implications of semiconductor chips. This will eventually encourage the setting up of fabrication and packaging facilities here. As far as cooperation with Taiwan is concerned, there is an inherent opportunity in old technology. Chips that are greater than or equal to 90 nm are still valid in applications like high voltage devices, electric vehicles, solar energy systems etc. Therefore, New Delhi and Taipei can explore the possibility of forming joint ventures that bring these kinds of technology to India. After all, there is a big market within the country. The intermittent availability of natural resources like water, electricity, land etc., are no longer a significant concern in India. There is, however, a pressing need to develop human resources in the semiconductor industry. In this regard, the Shastra University in South India has recently signed a memorandum of understanding with the Asia University and Yuan Ze University in Taiwan to build expertise in Very Large Scale Integrated (VLSI) design and manufacturing. Under the MoU, it is proposed that fifty students from India will travel to Taiwan to work on advanced semiconductor manufacturing. Backed by robust industrial support, such ventures can go a long way in fostering the required talent pool.

SEMICONDUCTOR DESIGN MARKET IN INDIA (US$ BILLION)



Source: Department of Electronics & Information Technology; Indian Semiconductor Association; E-Estimated; CAGR - Compounded Annual Growth rate

AR. NO. 09

DECONSTRUCTING THE TAIWANESE MODEL

The semiconductor industry is predicated on a complete and closed ecosystem that balances markets, investments, infrastructure, and technology

Mr. Premjith Krishnan , is the Deputy Director at Taipei Computer Association. This article is based on his views at the 104th virtual forum on 'Semiconductors and Supply Chains in Asia', jointly organised by the Synergia Foundation and the Taiwan Center for Security Studies.

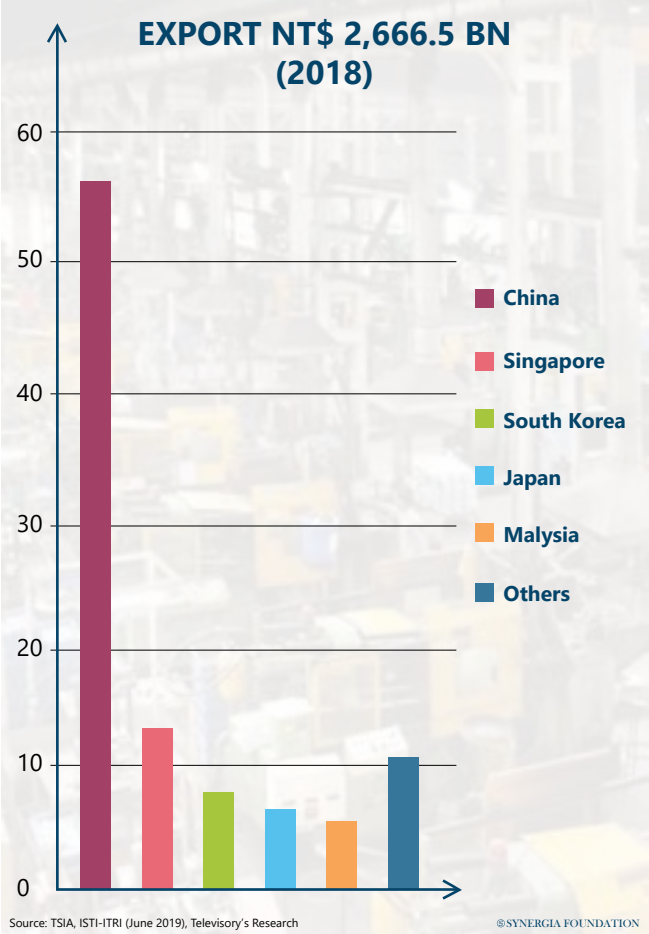
The escalating demand for semiconductors in the aftermath of the COVID-19 pandemic has produced supply chain constraints, making this is an opportune time to explore collaboration between India and Taiwan. The increased adoption of technology across all sectors and regions has created a global market for chips, which is estimated to reach 522 billion dollars by the end of 2021. In fact, companies like the International Green Chip (IGC) expect a year-on-year growth of 12.5 per cent over the coming years. Predictably, therefore, the proliferation of new technologies and data services has shone the spotlight on the global foundry market.

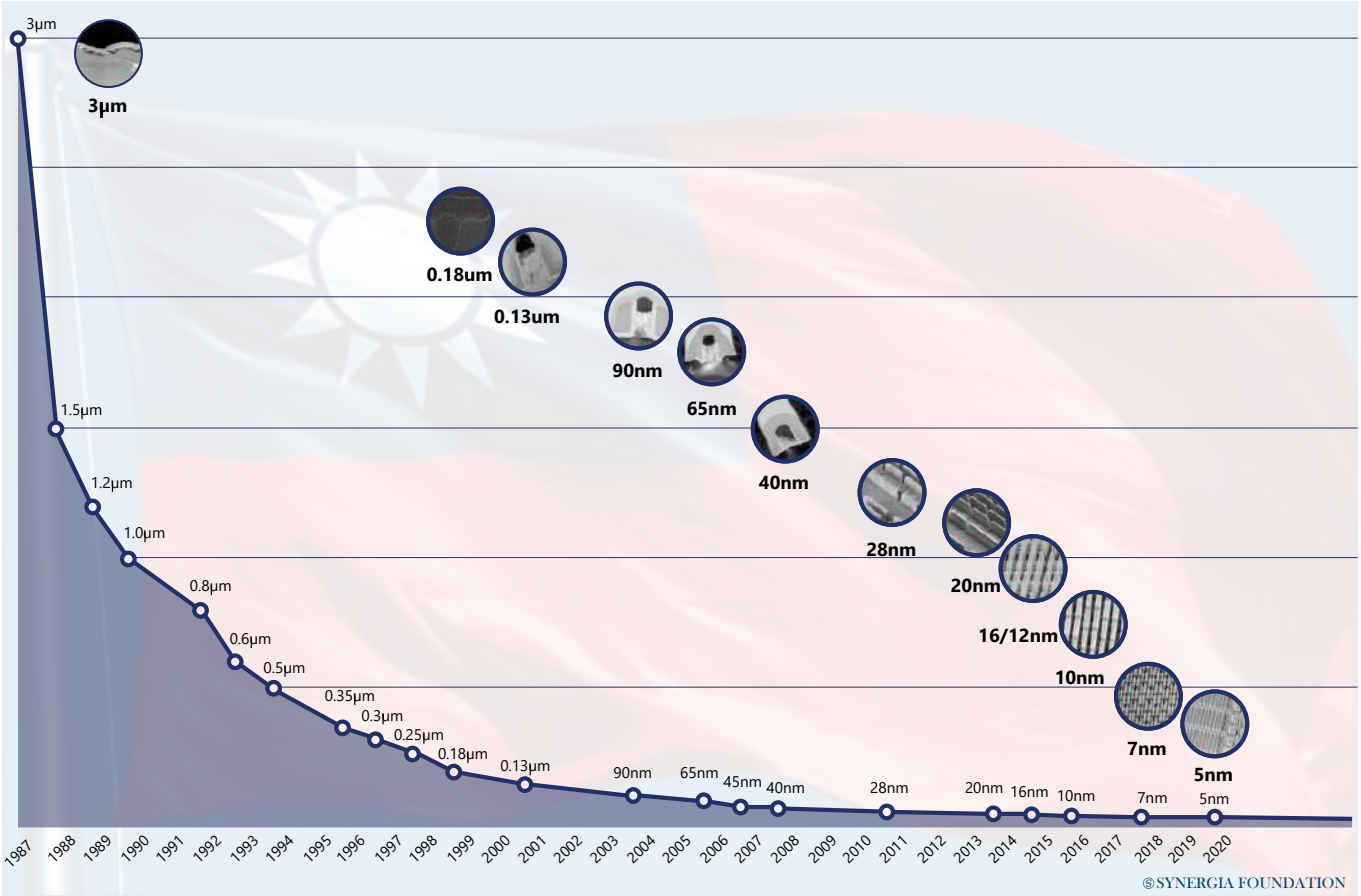
GROWTH STORY

Currently, Taiwan dominates the outsourcing of chip manufacturing. Having begun its journey almost four decades back, the country's path towards becoming the largest semiconductor supplier is truly remarkable.

Many of its entrepreneurs, who pursued their education and industrial experience abroad, deserve the credit for bringing this technology into the country and stimulating growth. The Taiwanese government, too, was proactive in implementing a unique set of policies at the right time. It not only helped to refine the capital market in the direction of equities, but also contributed substantial research and development (R&D) support for the Industrial Technology Research Institute (ITRI).

Now, the industry has reached such a stage that it





comprises 238 fabless design companies, 37 packaging and testing companies, 15 fabrication companies, 11 wafer suppliers, seven substrate suppliers, three mask makers and four lead frame companies. Over the last year, its contract manufacturers together accounted for more than 60 per cent of the total global foundry revenue.

Much of this success has been attributed to the stellar performance of one firm, namely the Taiwan Semiconductor Manufacturing Company (TSMC). At present, TSMC garners almost 54 per cent of the total foundry revenue. As designers and manufacturers embark on a continuous quest to make chips smaller and smarter, TSMC has emerged as one of the primary foundries that can manufacture the most advanced chips. In fact, it is gearing up to produce next-generation 3nm chips, with reports suggesting that the process might commence as early as 2022.

A SUPPORTIVE ECOSYSTEM

In Taiwan, the entire semiconductor ecosystem is located well within a distance of a few hundred miles. The industrial cluster is characterised by a vertically disintegrated infrastructure, where different companies focus on particular areas of expertise, as opposed to mastering the entire supply chain. In fact, many of them are small and medium enterprises. Therefore, Taiwanese semiconductor suppliers will invest or move to a new market only if the bigger players along the supply chain decide to do. Given that the fab is overly complex in terms of its technology as well as commercial operations, any shift to new geographies and ecosystems will not be easy. It requires huge investments that support business and operational abilities, while taking into account the high level of obsolescence in this industry. As far as infrastructure planning is concerned, stable power and water supply are extremely critical. Apart from the availability of skilled labour,

> “it is important to structure labour management practices when operating in different geographies and cultures.”

This needs to be accompanied by a strong and long-sustaining policy framework in host countries.

DIVERSIFY AND ADAPT

The supply chain bottlenecks triggered by the pandemic have compelled many countries to explore models of self-reliance in the semiconductor industry. Moreover, internal and external security threats are pushing Taiwanese chip companies to diversify their investments in other geographies and get closer to the market.

Against this backdrop, Taipei needs to think outside the box. Given that India is a leading powerhouse of chip design, there are tangible opportunities for cooperation.

However, companies will need a helping hand from regulatory authorities and industry associations to adapt to new cultures and geographies. Joint ventures with Indian players or a memorandum of understanding (MoU) with organisations like the Indian Electronics and Semiconductor Association can go a long way in bridging these gaps.

AR. NO. 10

FOSTERING A VALUE CHAIN

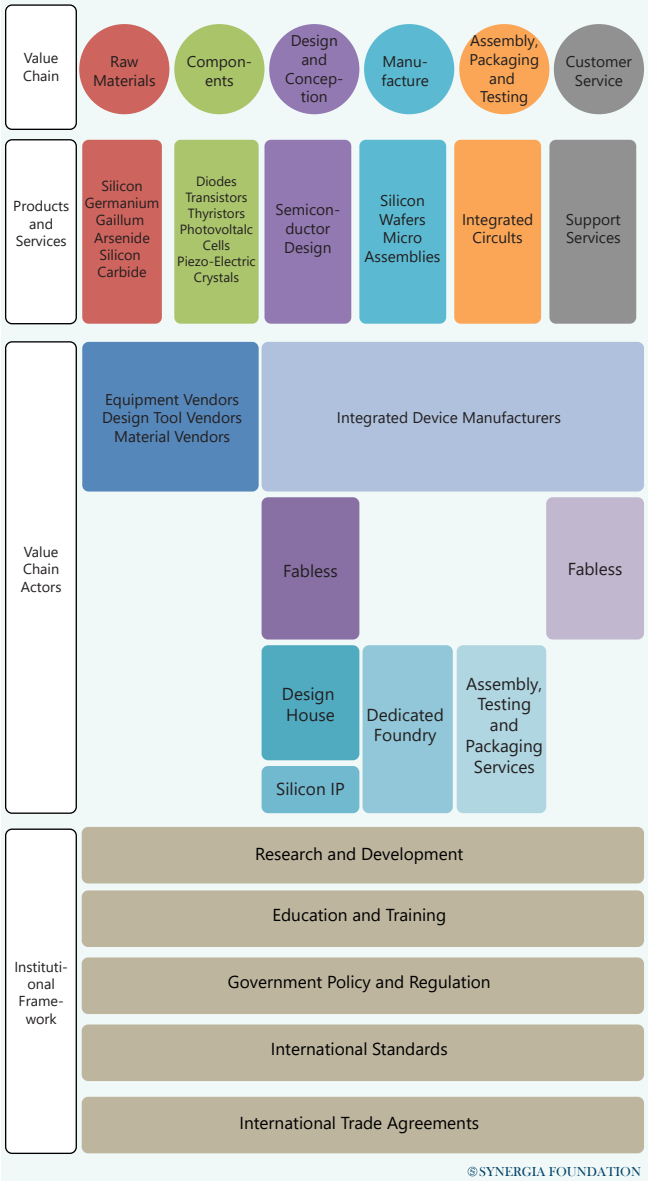
The Indian semiconductor ecosystem can be fortified by establishing multiple centres of excellence that focus on specific aspects of the supply chain

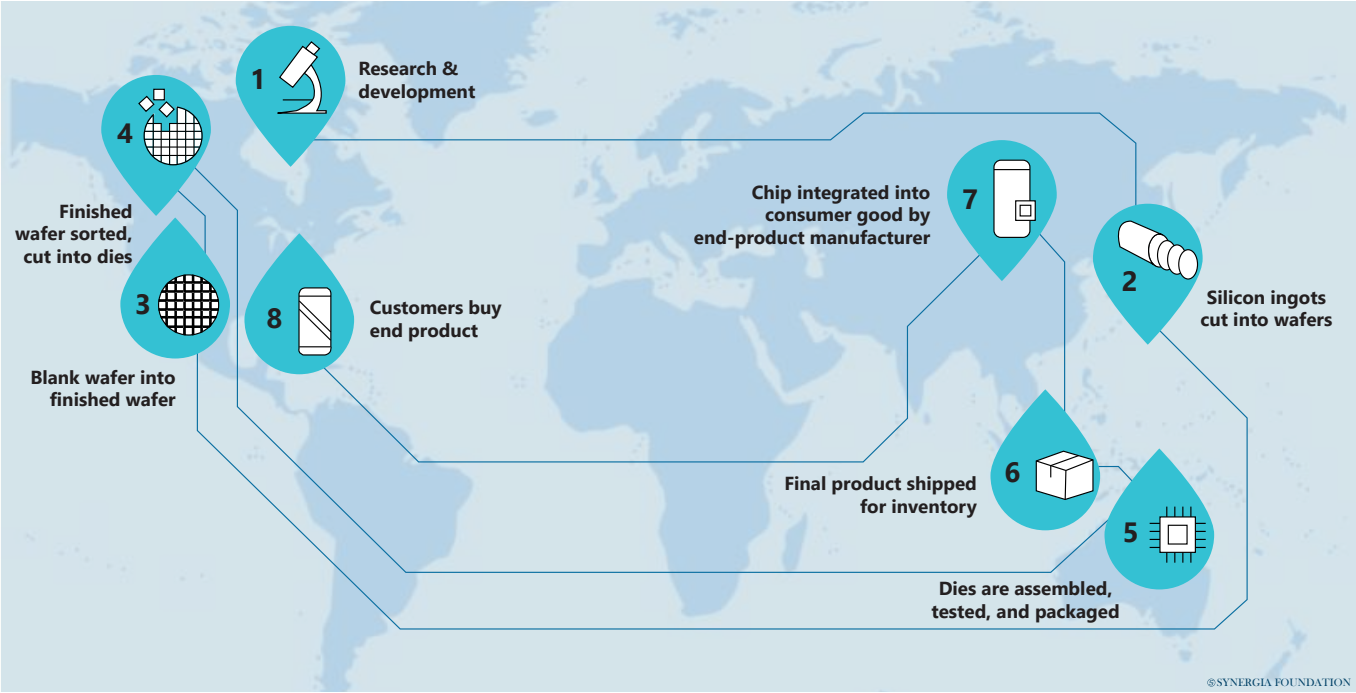
Mr. Sumeet Verma , is the Director of Strategy at Intel India. This article is based on his views at the 104th virtual forum on 'Semiconductors and Supply Chains in Asia', jointly organised by the Synergia Foundation and the Taiwan Center for Security Studies.

Intel has been an integrated device manufacturer (IDM) since its establishment in 1968. This means that it designs and builds its own semiconductors. Only a few months back, the current CEO of Intel - Patrick P. Gelsinger, had remarked that the company is "setting a course for a new era of innovation and product leadership". This primarily entails three components. Firstly, Intel will continue to build most of its products inhouse and expand its internal factory networks for ad-scale manufacturing. This means that additional investments will be poured into fabrication. In fact, the company has already announced an investment of 20 million dollars in Arizona. Secondly, Intel will expand the use of third-party foundries. It has already been using such facilities for specific equipment. The company will continue to do that, in order to ensure additional flexibility and scale. Thirdly, Intel will build a world class model for foundry business services, as it has hitherto been unable to do that effectively.

EMERGING TRENDS

For countries and businesses around the world, there are several external and internal factors that will inform their





semiconductor strategy going forward.

> Firstly, there has been a significant shift in the global semiconductor business model, spurred on by huge growth in Artificial Intelligence (AI)-based chips.

Over the next five years, it is expected that 80 per cent of the growth in semiconductor industries will be led by such AI-based chips. Secondly, geopolitical risks are forcing nation-states to locate their supply chain roles in-house and establish internal supply chain centres of excellence. Against this backdrop, India has developed a robust ecosystem for design, both in the pre-fabrication and post-fabrication stages. Moreover, supply chain roles like planning, sourcing, operations, and fulfilment have substantially shifted to the country and its neighbours. The Indian government has also been proactive in rolling out schemes to encourage electronics production. By creating a vision to incentivise manufacturing and assembly activities in India, it has prompted many companies to seriously explore the Indian market. Groups like Samsung and Tata are leading the pack, even as research organisations like the Indian Institute of Science develop compound semiconductor fabs like gallium nitrate.

> India's design capabilities are on par with some of the best players in the field, including those in the San Francisco Bay Area. It comfortably leads the pack in both semiconductor design and embedded system software. As a result, its design ecosystem can complement Taiwan's strengths in manufacturing, effectively creating a global powerhouse. As a simple first step, both sides can examine the possibility of cooperating in Outsourced Semiconductor Assembly and Test (OSAT) or Assembly, Testing, Marking and Packaging (ATMP) businesses. In this regard, the India Electronics and Semiconductor Association (IESA) will work assiduously with the Government of India to ensure an enabling policy environment.

Krishna Moorthy,
CEO and President of the India Electronics and Semiconductor Association (IESA).

SEEKING GLOBAL LEADERSHIP

As mentioned above, India has obvious strengths in design. Almost all the top design houses in the world, including Intel, Texas Instruments, Qualcomm, or Arm Ltd., have at least 30 per cent of their global workforce in India. At the same time, the supply chain ecosystem in the country is relatively weak. It does not rank anywhere close to the 'Top 20'. As a result, there is a pressing need to build up some aspiration in the system. A partnership with Taiwan can go a long way in bridging this gap. It is also important to look at the semiconductor value chain. Apart from actual fabrication, which requires wafer technology, there is core research and development (R&D), supply of raw materials, assembly, testing, packaging and finally, distribution. For India, a unique model that can be employed is the creation of multiple centres of excellence, where several firms come together and drive improvements across specific areas of the supply chain like procurement, operations, logistics and quality-based enginery.

To realise this objective, it is critical to identify and map what the semiconductor industry requires, apart from what the Indian government is already offering. There is also a need to nurture skillsets and facilitate knowledge exchange with countries like Taiwan. Eventually, these supply chain centres of excellence can help India to become a global leader in the semiconductor industry.

AR. NO. 11

MOVING BEYOND SILICON

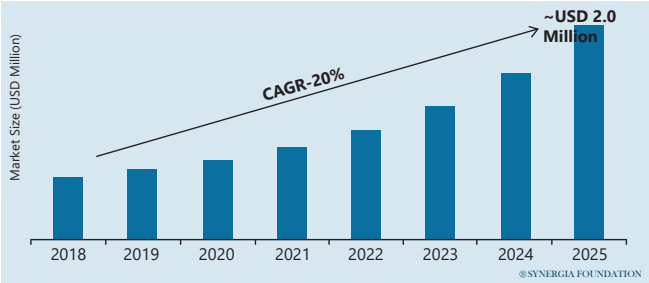
The compound semiconductor industry can act as the bedrock for an Indo-Taiwanese strategic partnership

Dr. R Muralidharan , is an Emeritus Professor at the Indian Institute of Science (IISc). This article is based on his views at the 104th virtual forum on 'Semiconductors and Supply Chains in Asia', jointly organised by the Synergia Foundation and the Taiwan Center for Security Studies.

There is a huge gap between India and the world in electronics manufacturing. Bridging this gap is a strategic and economic necessity. In fact, there are ongoing efforts by the Government of India to establish a complementary metal oxide semiconductor (CMOS) foundry in the country. Generally, the fab is perceived as a silicon foundry of sub-50 nm or sub-100 nm gate length and feature size. However, there are other emerging areas like Gallium Nitride (GaN) electronics that also show potential. Like silicon, they can be extremely useful in supporting sub-systems like e-vehicles, power converters, solar inverters etc. GaN RF electronics have also emerged as a key technology for 5G applications.

> "Establishing fabs for the production of GaN devices is relatively less expensive."

The obsolescence rate is also not high. All these factors make a strong case for setting up a foundry that focusses on both materials and device production. The Indian Institute of Science (IISc) has submitted a detailed project report on establishing a GaN foundry to the Government of India. The semiconductor industry, however, is a long-term investment that is capital intensive. In most countries, governments have either completely funded the initial nucleation or infused funds into foundries, as and when needed, to maintain a strategic edge. It is well-established that the backbone of semiconductor production is situated in Taiwan. They have also established a strong base in the field of GaN technology. Against this backdrop, compound semiconductors form a possible avenue for bilateral collaboration between India and Taiwan. It could form a base for Taiwanese chip companies to diversify their investments in India, eventually creating a supply chain centre of excellence. To support this endeavour, India has a wealth of human resources. Academic institutions like the IISc, the Indian Institutes of Technology (IITs) as well as national laboratories have the sufficient expertise to address technical challenges relating to GaN fabs. As part of various government initiatives over the past fifteen years, students have also been trained in 'fab-like' facilities, where they learn the techniques and designs employed in semiconductor manufacturing. Currently, however, such skilled manpower is forced to pursue employment opportunities abroad. By facilitating the right ecosystem in India, their talent can be effectively utilised in the country.



DYNAMATIC TECHNOLOGIES LIMITED

COLLABORATIVE
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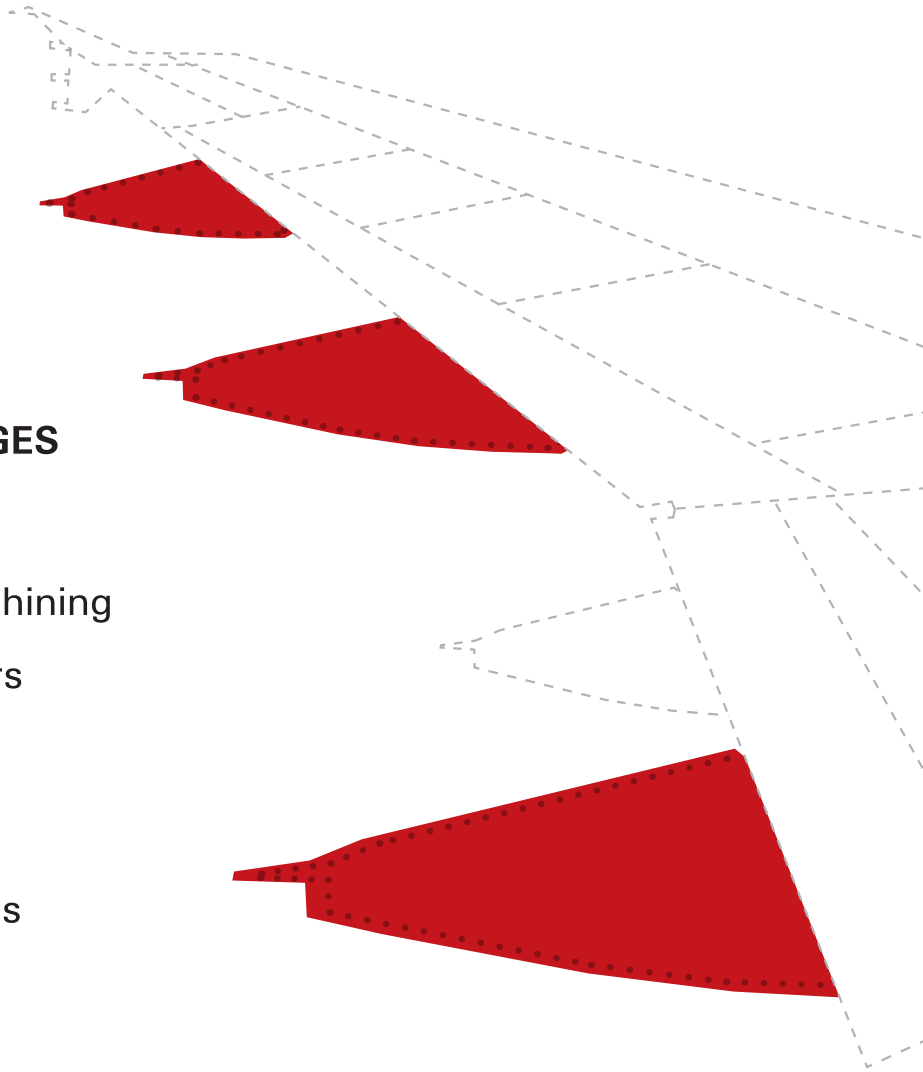

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AR. NO. 12

CHALLENGES FOR A SHIFTING SUPPLY CHAIN

The Taiwanese semiconductor industry is gearing up to meet the challenges of disruption in the traditional supply chain through innovation and a multipronged approach


Richard Chen and Aswini Kumar are researchers with the Taiwan Center for Security Studies.

For the past few decades, the majority of cutting-edge tech semiconductor chips manufacturing has been concentrated in East Asia, with more than half of the global market getting their chips from Taiwan. This makes the role of Taiwan in the US-China tech competition unparalleled. However, this may change with the American decision in June (Federal Supply Chain Review) to bring onshore the production of semiconductor chips. As a ripple effect, it has nudged companies and countries to "bring home" production of the chip foundries.

Taiwan has monopolised the production of the world's most advanced chips, with 92 per cent of leading-edge chip (<10nm) production in the global economy coming from the island. Taiwanese titans in the chip industry, such as Morris Chang's TSMC (Taiwan Semiconductor Manufacturing Company) and Terry Guo's Foxconn (HonHai Precision Industry), amongst others, have founded and advanced the foundry business model that the world's semiconductor industry current runs on.

EFFECTS OF GEOPOLITICAL TENSIONS

However, with the rising tension in the geopolitics of the region, Washington, with the support of its allies and partners in India and Japan, have prodded tech companies to begin seriously considering onshoring production in critical industries in the supply chain. In June of this year, the White House released its "100-Day Supply Chain Review Report", which points out the overreliance of fabrication in the chip industry in Taiwan as potentially catastrophic in the event of any shocks in the current state of this supply chain. The report further instigates a reconfiguration of the current model, citing current disruptions such as the pandemic as already sending the world into an economic slowdown and at risk of affecting neighbouring industries such as vehicles, electronics, and/other digital infrastructure.

Intel Foundry Services has focused on utilising its competitive advantage as an integrated device manufacturer (IDM) and has already signed with Amazon Web Services (AWS) and Qualcomm for the next few years. Further,

they are announcing that they intend to catch up to TSMC and Samsung by 2025 with their five sets of chipmaking technologies to be laid out in the next few years.

MEETING THE CHALLENGE

Taiwanese tech giants and semiconductor titans have also made clear their intention in solidifying and repositioning themselves in the ongoing supply chain reconfiguration.

> "Vertical and horizontal integration for the Taiwanese semiconductor fabrication industry is currently at a pivotal moment."

The dilemma is whether to shift its business model to adapt and go along with these reconfigurations or to evolve and invest in diversifying both onshore and offshore. Thus, we are seeing plans of Taiwanese companies moving into the U.S., Japan and looking ahead, perhaps even in Germany. Following the current global chip crunch, TSMC might eyes plans for constructing chipmaking plants in other countries and so diversify the supply chain. In April, it announced that it would spend $100 billion through 2023 to meet the "structural and fundamental increase" in global chip demand. TSMC chairman Mark Liu, during a virtual meeting with shareholders, has expressed confidence in the changes visible in the global supply chain.

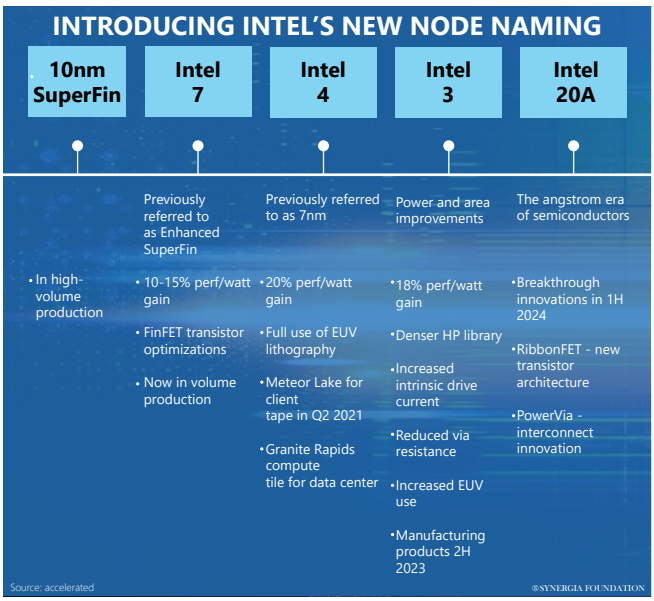
He emphasised that "as the company is working closely with its clients, they are expected to share the burden of the costs when TSMC expands its production globally, which is expected to maintain its profit margin... TSMC will achieve its long-term goal to have its gross margin top 50 per cent." Thus, redefining its strategy in light of the regional geopolitics and external shocks such as COVID-19, TSMC has approached this reconfiguration with accelerated fervour. In the past, the company has continuously focused on upgrading its technologies as well as juggling expansion both within Taiwan and offshore, particularly in the mainland. At the same time, it is keeping the most high-end fabs in the northern Taiwan city of Hsinchu.

At the bequest of foreign government and stakeholders, TSMC has directed more of its ventures into countries like Japan and the U.S., with potential others down the line. Around 62 per cent of TSMC's revenue came from North American clients in 2020. This comes at a time for TSMC—despite an acceleration of its expansion plans—as a sign of good tidings as it views a boom in business.

The company's CEO, C.C. Wei, recently said in a conference call with investors: "As a leading pure-play foundry, TSMC has never been short on competition in our 30-plus-year history, yet we know how to compete". Its plans for the first plant in Japan may work well with considerable geographical and work culture, as Tokyo urges companies to enlarge semiconductor production onshore and demands from large Japanese client Sony. It would mark a significant departure from TSMC's decades-long strategy of preserving most of its production in its home market. However, TSMC will likely own and run the factory independently to avoid any conflicts of interest.

RIDING OVER THE BUMPS

Yet, doing business in other countries could very well differ in many ways, including local concord policies, facilities, and advancements. Thus, TSMC and others cannot employ the same business model approach in every case. Especially its endeavours in looking towards developing countries, considering local resources and amenities favouring the bottom-line profit margin. Taiwanese firms should look at growing local demand-supply and market how this aid a mutual win-win condition. The semiconductor industry as it stands today is a very sophisticated one; construction of its chip foundries is not a tranquil task. There are six major integral factors required for developing such a sophisticated ecosystem. (1) Feasible infrastructure like land, electricity, water supply, (2) Human resources, (3) Facilities like logistics and precision equipment, (4) Supporting Industries like gas and chemicals, (5) Market competition, and (6) High Capex Investment. The major challenges these companies would face during the construction of their foundries in host countries are feasible conditions, encouraging government policies and a preliminary assessment for any conflict on Centre-State policies concerned. Therefore, moving forward, SWOT analysis is the foremost requirement to figure out how efficient the host country is for accommodating their new branch foundries and adapting their business models and assimilate with the local geographies, work culture. Taking damage control approach (e.g., Wistron labour issue in India) if any issues arise, diplomatic handling of such is significant for sustainable operation with better cooperation. To ensure ease of doing business, local liaison agencies and personnel would be invaluable. The best would be to identify existing ATMP (Assembly, Testing, Marketing and Packaging) companies that are willing to collaborate. HR can be empowered in chipmaking via universities and research centres collaborations. Joint ventures and collaborations can be beneficial for not just Taiwanese foundry businesses looking to expand but also local partners abroad. Thus, TSMC should look before it leaps.



AR. NO. 13

EMBARKING ON THE CHIP JOURNEY

India's quest for self-sufficiency in semiconductors hinges upon a sustainable fab manufacturing, created through a 360-degree ecosystem approach

Mr. Ajay Jalan , is the Founder and Managing Partner of Next Orbit Ventures, a multi-asset fund manager that invests in the debt and equity of growing companies. The company has submitted a proposal for setting up semiconductor fabs in India, in response to the government's call for 'expressions of interest'.

Semiconductors are the brains and heart of electronics that are all-pervasive in every aspect of modern life - consumer electronics, automotive and transport, laptops and computing, smartphones and devices. They also power future technologies in sectors like Artificial Intelligence, Internet of Things, Robotics, Virtual Reality, Industry and Automation, Aviation and Aerospace, Defence, Medical Science etc. Semiconductors, consisting of digital, analogue, and memory, constitute 20 - 60 per cent of the electronics value chain, a ratio that is increasing with every passing year. In the design space, the Intellectual Property is mainly concentrated in U.S.-based companies like Intel, AMD, Qualcomm, Nvidia etc. However, 70% of the manufacturing is done by Taiwan-based companies such as TSMC and UMC.

THE INDIAN SCENARIO

With its significant population size, India boasts of a substantial electronics goods market valued at $180 billion in 2018 and is forecasted to reach $710 billion by 2025. The demand for semiconductors has also been rising at a matching pace and grew from $18 billion in 2018 to an estimated $52 billion by 2025 (Frost & Sullivan Study 'India's Electronic & Semiconductor Market' for Next Orbit Ventures). The major growth drivers are large market demand across tiers, increasing per capita income, Easy loan availability for buying electronics etc. Despite such a big market and huge growth in this sector, India only captures around 5-10 per cent of the total value through assembly of electronics.

The remaining 90% is still dependent on imports. It is, therefore, clear that if India must create a self-sufficient and sustainable electronics manufacturing ecosystem, an indigenous semiconductor manufacturing capacity will remain at its core.

BUILDING THE ECOSYSTEM

The reality is that today India is exporting 100 per cent of its semiconductors and lacks any ecosystem or infrastructure to start semiconductor manufacturing. It will be a big task to build the first-ever commercial fabrication plant. Given that semiconductors are the core of electronics, it is mandatory for any country (and for India, even more so) to foster a complete electronics manufacturing ecosystem. Clearly sensitive to the need of the times, the Indian government has issued a 'Global Expression of Interest' last December for the setting up of semiconductor plants in India. The 'Nasdaq' of July 19th ran a story that around twenty proposals have been floated, with three having reached advanced stages, which includes one by a consortium that is led by Next Orbit Ventures.

To mitigate the risks of its obvious vulnerabilities, India should go with a step-by-step approach by starting with n Analog Fab for 65nm technology node as it is more feasible to test the waters.

SILICON CONTENT GROWING AS EVERYTHING GETS SMARTER

Semi content per unit	2015	2020	2025F	
HIGH END SMARTPHONE	$100	$170	$275	+62%
AUTO (GLOBAL AVERAGE)	$310	$460	$690	+50%
DATACENTER SERVER (CPU + ACCELERATOR)	$1,620	$2,810	$5,600	+99%
SMARTHOME (GLOBAL AVERAGE)	$2	$4	$9	

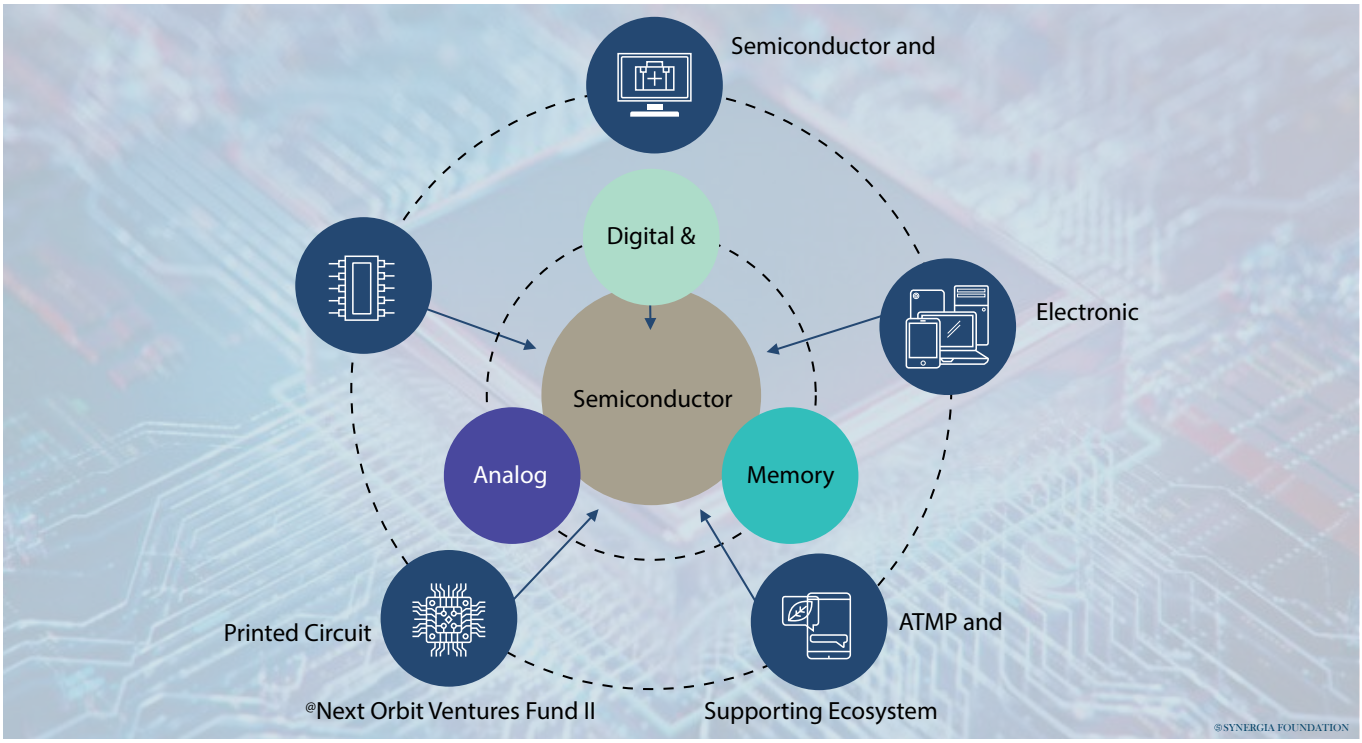
Source: Applied Materials

> "Analog requires less investment compared to digital fabs and its technology is comparatively less complex."

Once the ecosystem and infrastructure are in place, digital fab companies may be encouraged to build their fabs in India and utilise the advantage of the Indian talent pool and other resources. India can initiate and sustain semiconductor fab manufacturing, if it goes with a 360-degree ecosystem approach of investing in fabs as well as companies like ATMP & EMS, PCB, design companies, component and products companies. World over, fabs are incentivised by the government of that country. TSMC was formed by 48 per cent incentives from the Taiwanese government, while the remaining investment was coerced through big corporate houses of the country. Recently the U.S. Senate passed a bill supporting $50 billion for onshore semiconductor manufacturing. South Korea is planning to spend $ 450 Bn.

In a similar fashion, the Indian government will have to support fab manufacturing with capital, fiscal support, infrastructure, and demand creation.

However, the government alone cannot make the fab project successful; corporate houses in India must also pitch in with their capabilities of execution, capital, and demand guarantee. This can pave the way for the country to become a global powerhouse in semiconductors.



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FACT SHEET

INSIGHTS | JULY 2021

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CYBER-PROOFING THE CHIP INDUSTRY

SYNERGIA FOUNDATION
RESEARCH TEAM

Today, semiconductor chips are commonly deployed in almost all modern electronics and computing systems. The proliferation of billions of Internet of Things (IoT) devices has increased the demand for customised application-specific integrated circuits (ASICs). The pervasive nature of these technologies, however, presents a unique opportunity for malicious actors to launch devastating cyberattacks. Physical hardware is as susceptible to cyber threats as software systems. According to experts, physical modifications to a single integrated circuit (IC) can lie undetected amongst the sheer number of valid components, owing to the complexity of ICs and microelectronics. Given that modern-day chips are incredibly sophisticated devices, consisting of billions of transistor components, they can be compromised during the processes of design, fabrication, assembly or testing. In other words, hackers can exploit vulnerabilities at any stage of the product life cycle. The manufacturing supply chain , in particular, is a a lucrative attack surface. Hardware attacks can take many forms. For example, active attacks like fault injection can result in IC malfunction and catastrophic system failures. Alternately, passive attacks such as side channel analysis may result in the leakage of secret information.

In fact, in 2018, researchers had studied a series of fundamental security flaws in computer chips, known as the 'Spectre and Meltdown'. All variants of this underlying vulnerability involved a malicious program that gained access to privileged memory, when it did not have the permission to do so, through a side-channel or an indirect attack. It had the potential to spill sensitive data like passwords and encryption keys from billions of computers, mobile devices as well as the cloud. When these flaws were exposed, it took companies like Intel nearly two years to patch their vulnerabilities. The use of counterfeit semiconductor components is yet another concern. These compromised systems can carry viruses or malware that affect a range of military systems and critical infrastructure. In a 2010 survey conducted by the U.S. Department Of Commerce, nearly 55% of IC manufacturers reported that they had encountered counterfeit versions of their products. Against this backdrop, it becomes important to prioritise hardware security, by combining the capabilities of the public and private sector. Government agencies can play an active role in devising standards and controls for the chips that are designed and manufactured by commercial players. An effective mitigation strategy should be predicated on the following factors:

- Institutionalisation of global best practices in hardware-related security standards, regulations and certifications.
- Improvement of testing procedures to detect corrupted or counterfeit chips before they are deployed in products.
- Elimination of security flaws in chip designs.
- Incorporation of a silicon-based 'hardware root of trust' that builds core security mechanisms into the actual hardware.
- Establishment of defensive protocols for integrated chips to detect, quarantine and shut down attacks, as and when they occur.

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