

Semiconductor Plants

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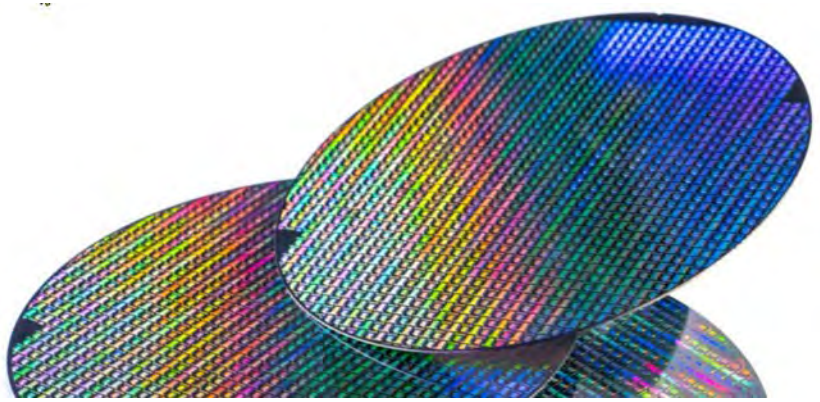
Mumbai, 26th May 2025



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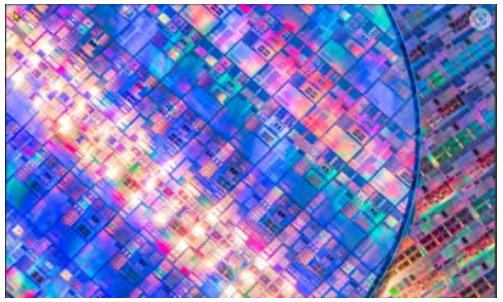

1 What is a Semiconductor, overview of Semiconductor Industries

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1. What is a Semiconductor, overview of Semiconductor Industries

What is a Semiconductor

- Semiconductors are materials which have electrical conductivity between conductors (generally metals like copper) and nonconductors or insulator (like most ceramics).
- The conductivity of semiconductors can be controlled by adding impurities, a process called doping, which allows the creation of different semiconductors like n-type and p-type, which are essential for building electronic devices.
- Semiconductors are typically from Silicon or Germanium or compounds materials such as Gallium Arsenide or Indium Phosphide.
- Semiconductors are the foundation of modern electronics and are essential components of a vast array of products including transistors, diodes, and integrated circuits.
- They are used to power electronics, solar cells and sensors in devices like computers, smartphones, and digital cameras, as well as in many other types of equipment and systems in fields ranging from telecommunications to healthcare to transportation.

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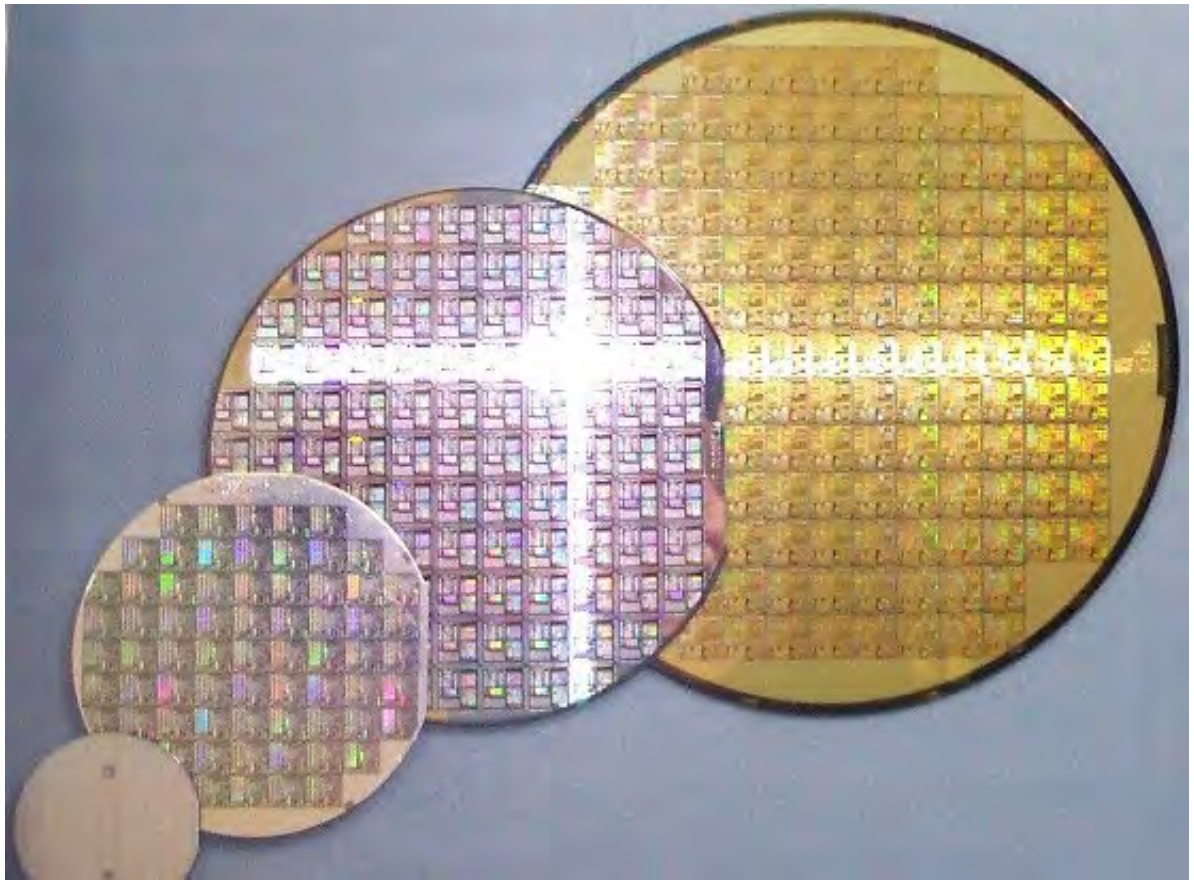
What is a Wafer

A wafer is a substrate or a thin slice of semiconductor, such as a crystalline silicon (c-Si, silicium), used for the fabrication of integrated circuits



Silicon substrate

Silicon wafers are available in a variety of diameters from 25.4 mm (1 inch) to 300 mm (11.8 inches). Semiconductor fabrication plants, colloquially known as *fabs*, are defined by the diameter of wafers that they are tooled to produce. The diameter has gradually increased to improve throughput and reduce cost with the current state-of-the-art fab using 300 mm, with a proposal to adopt 450 mm Intel, TSMC, and Samsung were separately conducting research to the advent of 450 mm "prototype" (research) fabs, though serious hurdles remain.

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Size of the Wafer (often known as Substrate)

The size of a semiconductor substrate, can vary depending on the requirements of the semiconductor devices being produced. Diameter of the wafer is the common measurement used rather than the thickness. Wafer sizes have incrementally increased to allow for more integrated circuits to be built onto a single wafer, improving manufacturing efficiency and reducing cost per chip.

150mm (about 6 inches) - used in older or specialized processes.

200mm (about 8 inches) - still widely used for a variety of technologies.

300mm (about 12 inches) - the most common size for modern, high-volume semiconductor manufacturing.

TABLE 3

Number of Wafer Fabs by Capabilities and Fab Location

Wafer Size (in)	United States	Japan	Taiwan	South Korea	China	Total
2	10	5	19	2	49	85
3	20	4	3	0	9	36
4	63	36	19	8	57	183
5	5	15	3	2	14	39
6	84	74	30	9	64	261
8 (200 mm)	61	53	26	12	36	188
12 (300 mm)	33	29	44	32	41	179
Total	**276**	**216**	**144**	**65**	**270**	**971**

Note: Eight inches is roughly equivalent to 200 nm, and the two are often used interchangeably when referring to silicon wafer diameter size. Twelve inches is roughly equivalent to 300 nm, and the two are often used interchangeably when referring to silicon wafer diameter size.
Source: CSIS analysis; "World Fab Forecast," SEMI, March 14, 2023, https://www.semi.org/en/products-services/market-data/world-fab-forecast.

CSIS | WADHWANI CENTER FOR AI AND ADVANCED TECHNOLOGIES

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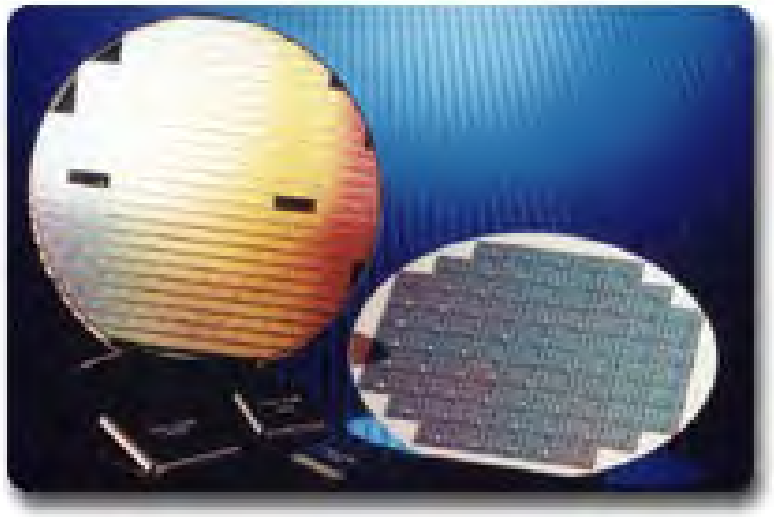
What is a Chip (IC)?







Wafer

↓

Chip

↓

Contain Millions of Transistors

- Hundreds of Different Steps
- High Temperatures
- Small Features
- Measures less than a micron in width

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Integrated Circuit Chip

An IC chip is a small electronic package of pathways, circuits, and transistors that work together to carry out a specific task – or a series of tasks.

Quality of the wafer is a crucial factor in the manufacturing process.



Reference: Wafer vs. Chip Distinctions (waferworld.com)

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Applications of a Chip (IC)

Industries	Applications
Telecommunications	Voice & Data Equipment
Wireless Technologies	Cellular phones
Computers	Desktop & Laptop, Workstations
Networking	Routers, Switches & Modems
Consumer Electronics	TV, DVD, Video, Audio systems
Home Based Products	Appliances, Security systems
Automotive	Navigational Systems, Engine Tracking, Mechanical Control systems
Space	Space Shuttles, GPS
Medical	Monitoring Systems & Analysis tools

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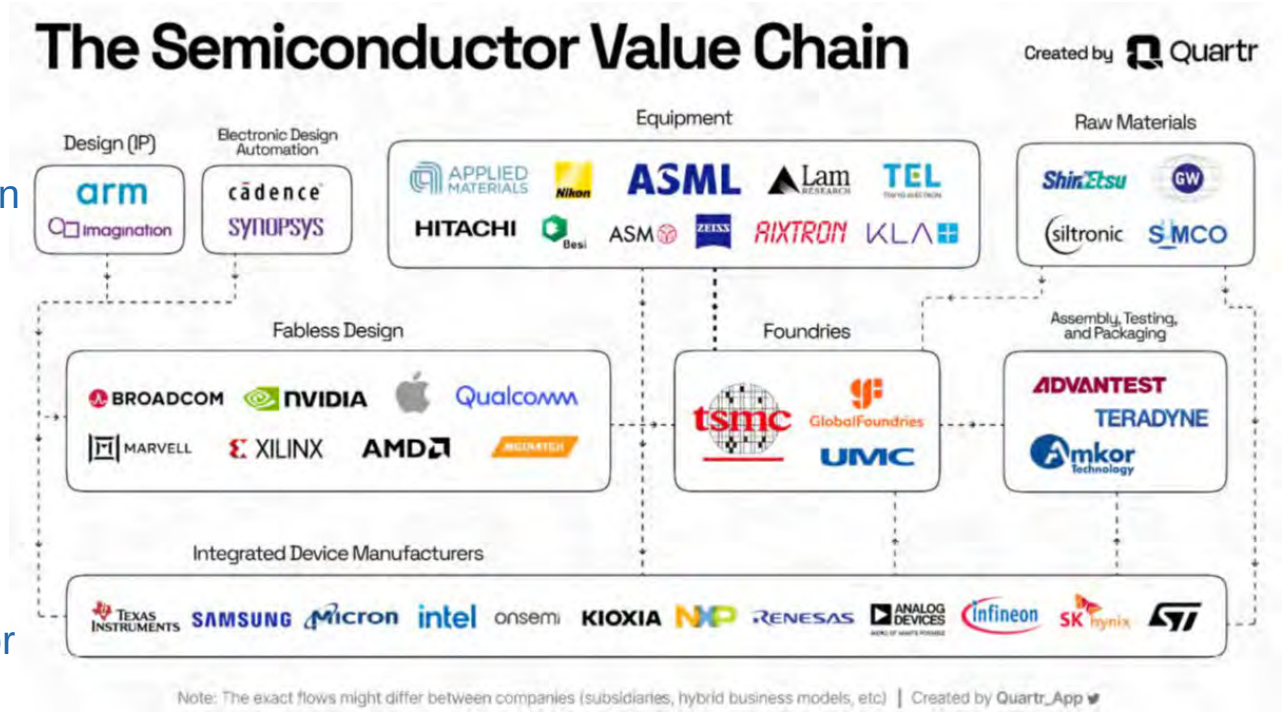
The Semiconductor Value Chain (7 categories of companies)

1. Raw Materials and Chemical Suppliers – silicon wafers, thin films, gases, fluids and chemicals
2. Foundries – Make chips for fabless design firms
3. Electronic Design Automation (EDA) - develop software tools including designing intellectual property (IP) for design and verify semiconductor chip
4. Fabless Design – focus on the design and development of semiconductor chips
5. Equipment - specialize in machineries and tools for chip production
6. Assembly, Testing and Packaging – OSAT companies are third party packaging and testing services to semiconductor manufacturers
7. Integrated Devices Manufacturers (IDM) – Design and manufacturer in their own fabs and sell their own chips



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2. Semiconductor Manufacturing Process

Manufacturing Process
3 main categories of Production Streams



- **Silicon Ingot Manufacturing**
- **Wafer Production**
- **IC Packaging/Testing**

Most expensive, complex and hazardous is during wafer production.

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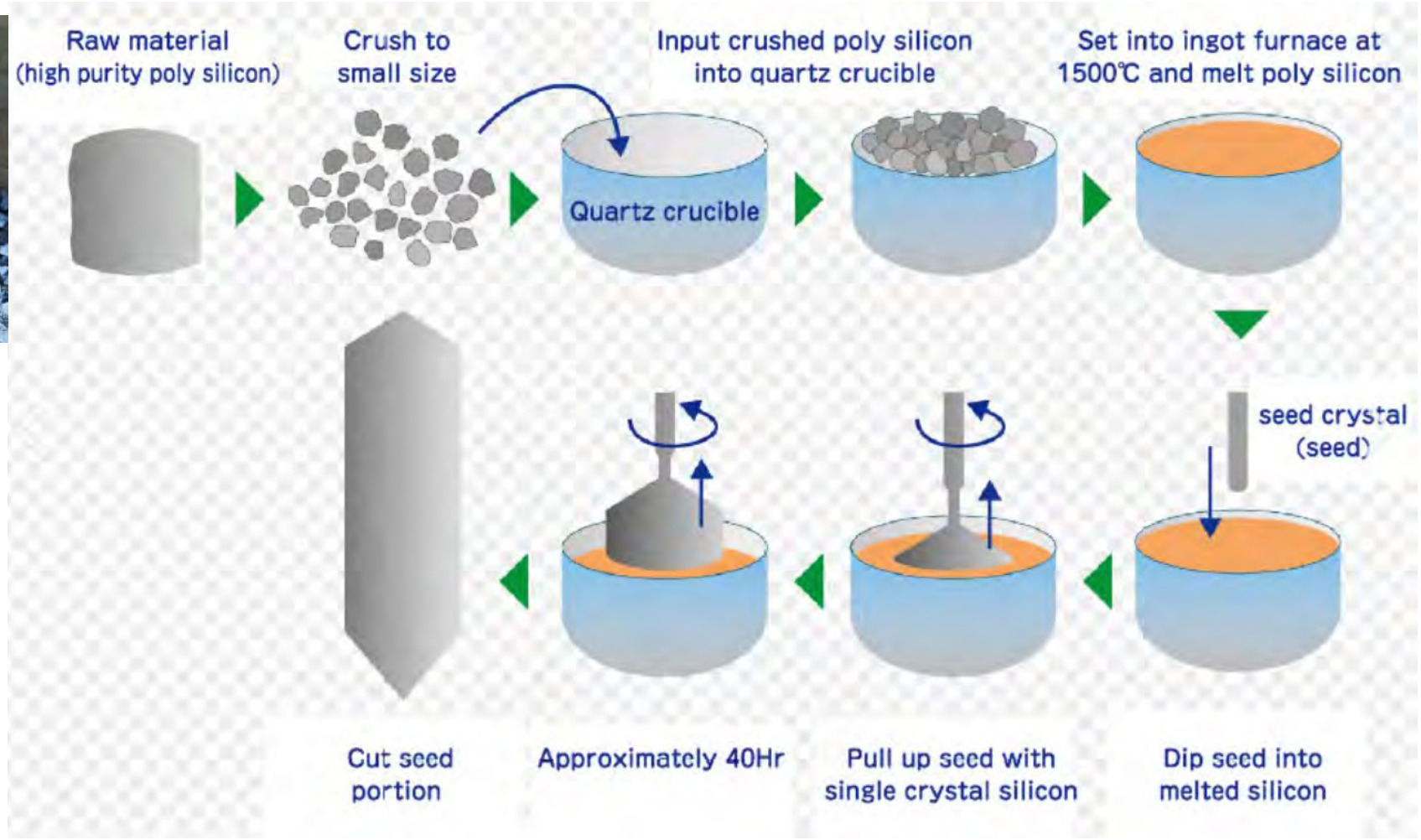
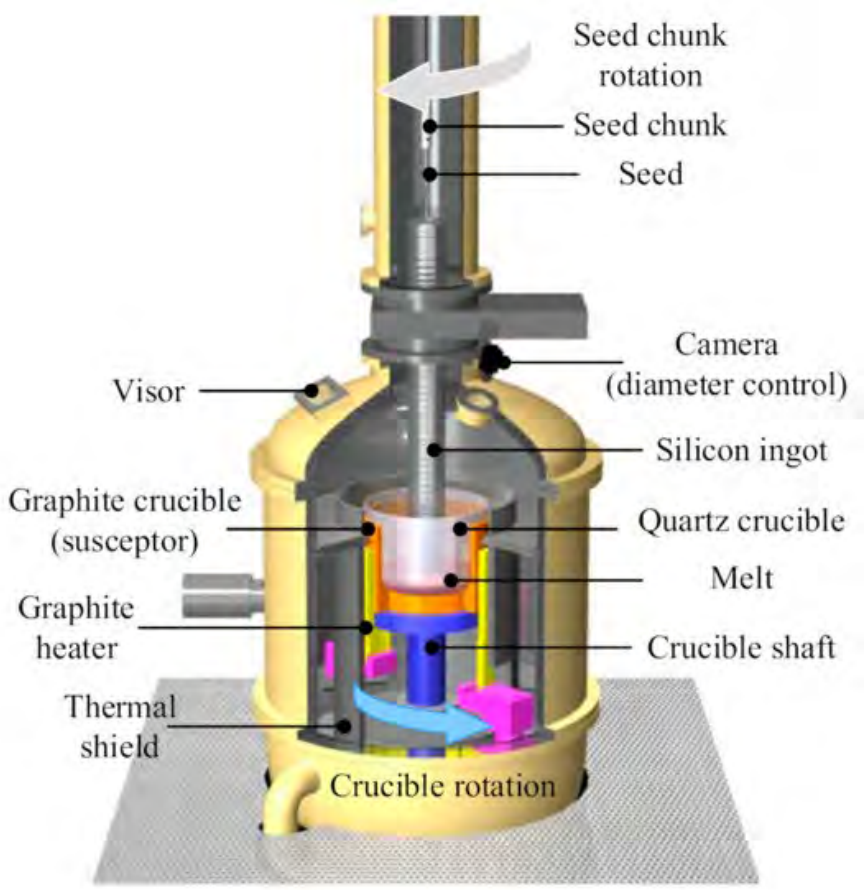
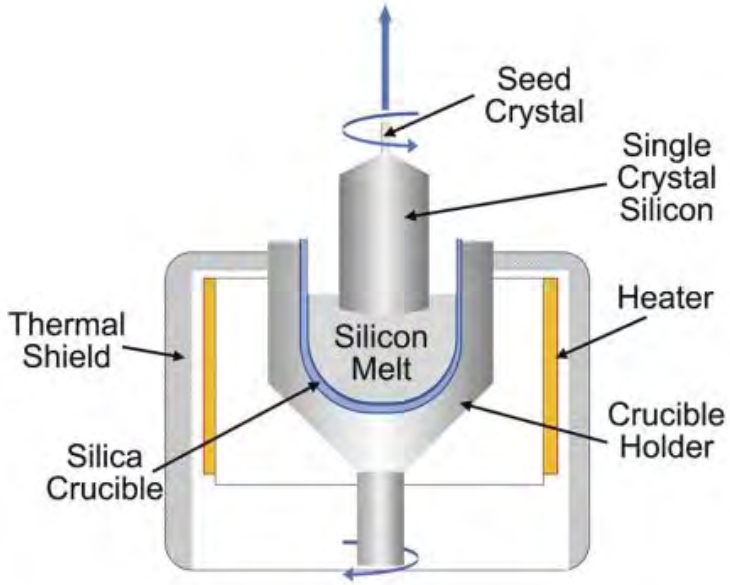
Silicon Ingot Manufacturing





Silicon Crystal Growth Furnace / Quartz Crucible





(a)

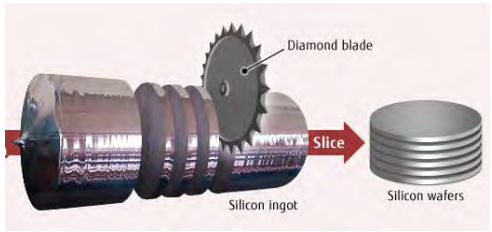


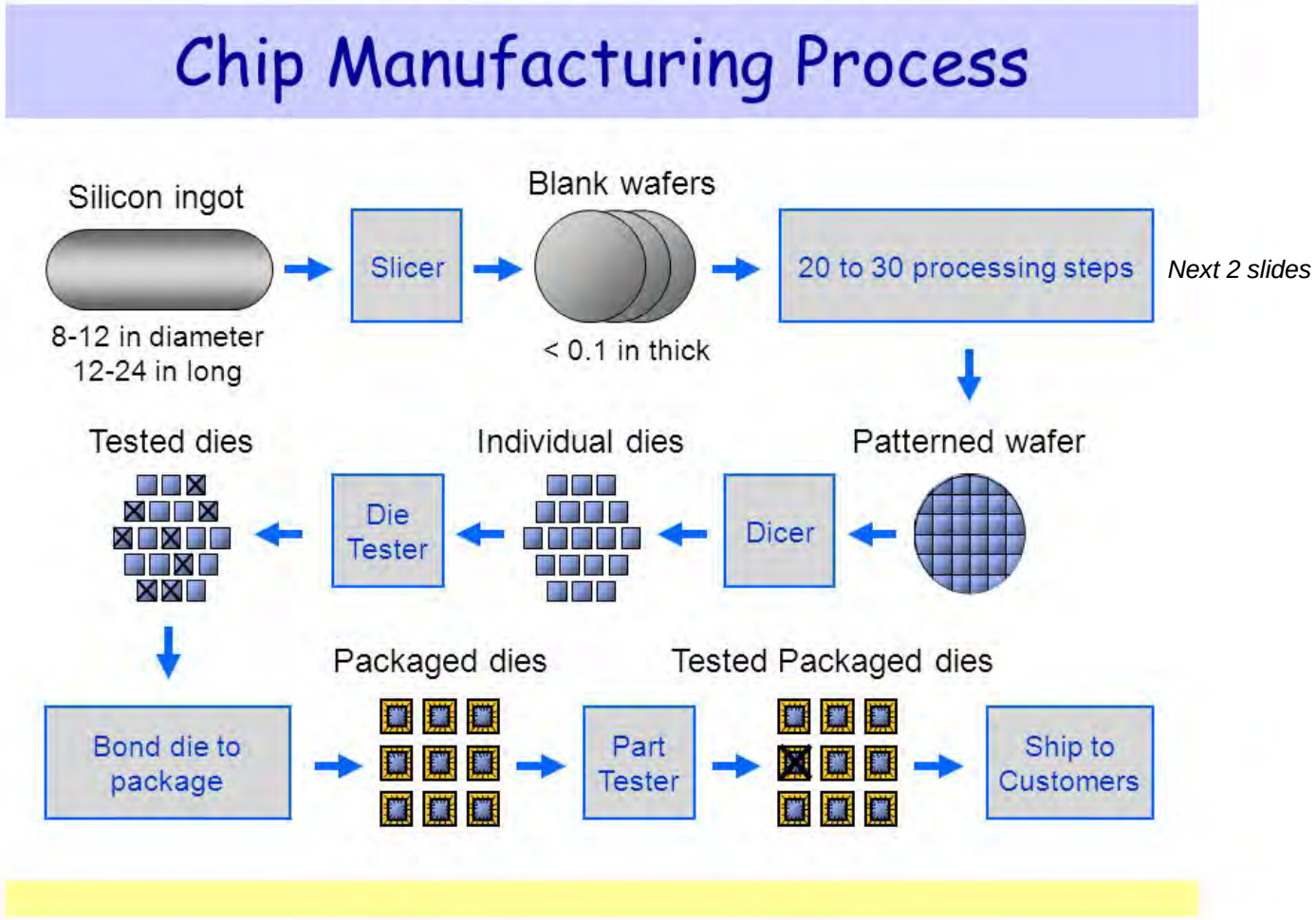
(b)

A Deep Learning Based Dislocation Detection Method for Cylindrical Crystal Growth Process

Wafer Production







Next 2 slides

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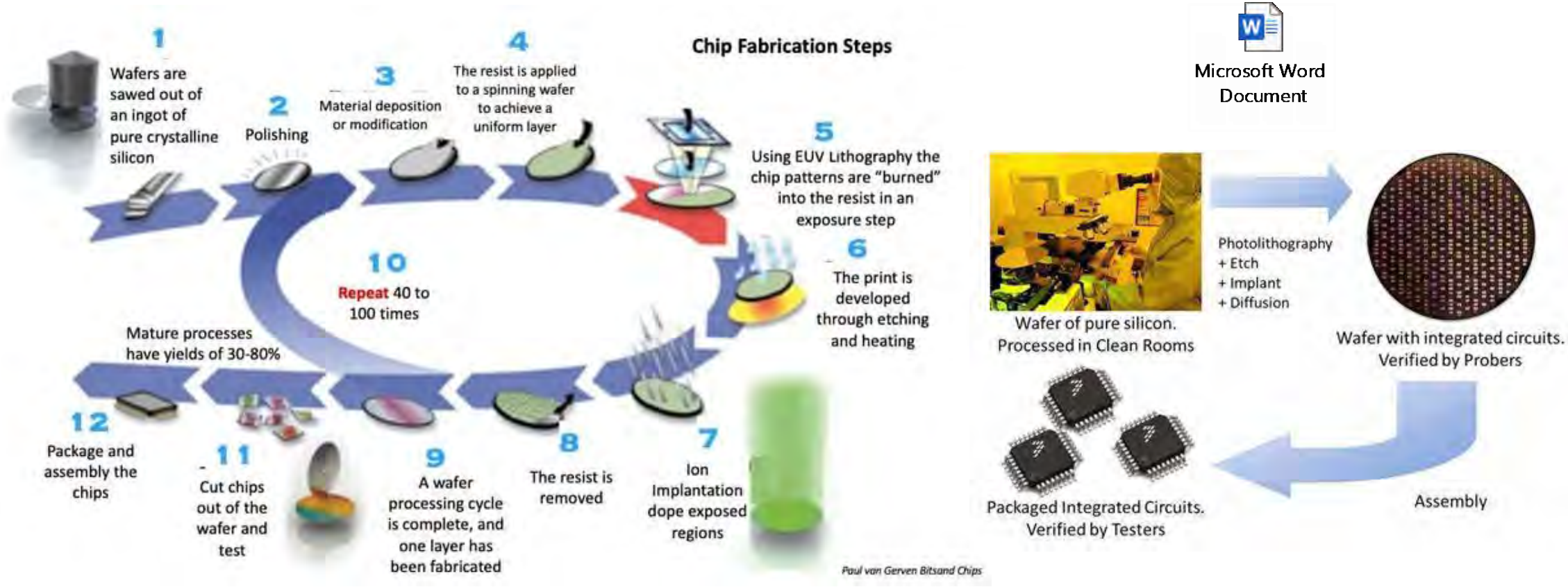
Steps involved in turning a Wafer into an Electronic Device

IC Chip fabrication Steps – Semiconductor manufacturing process overview



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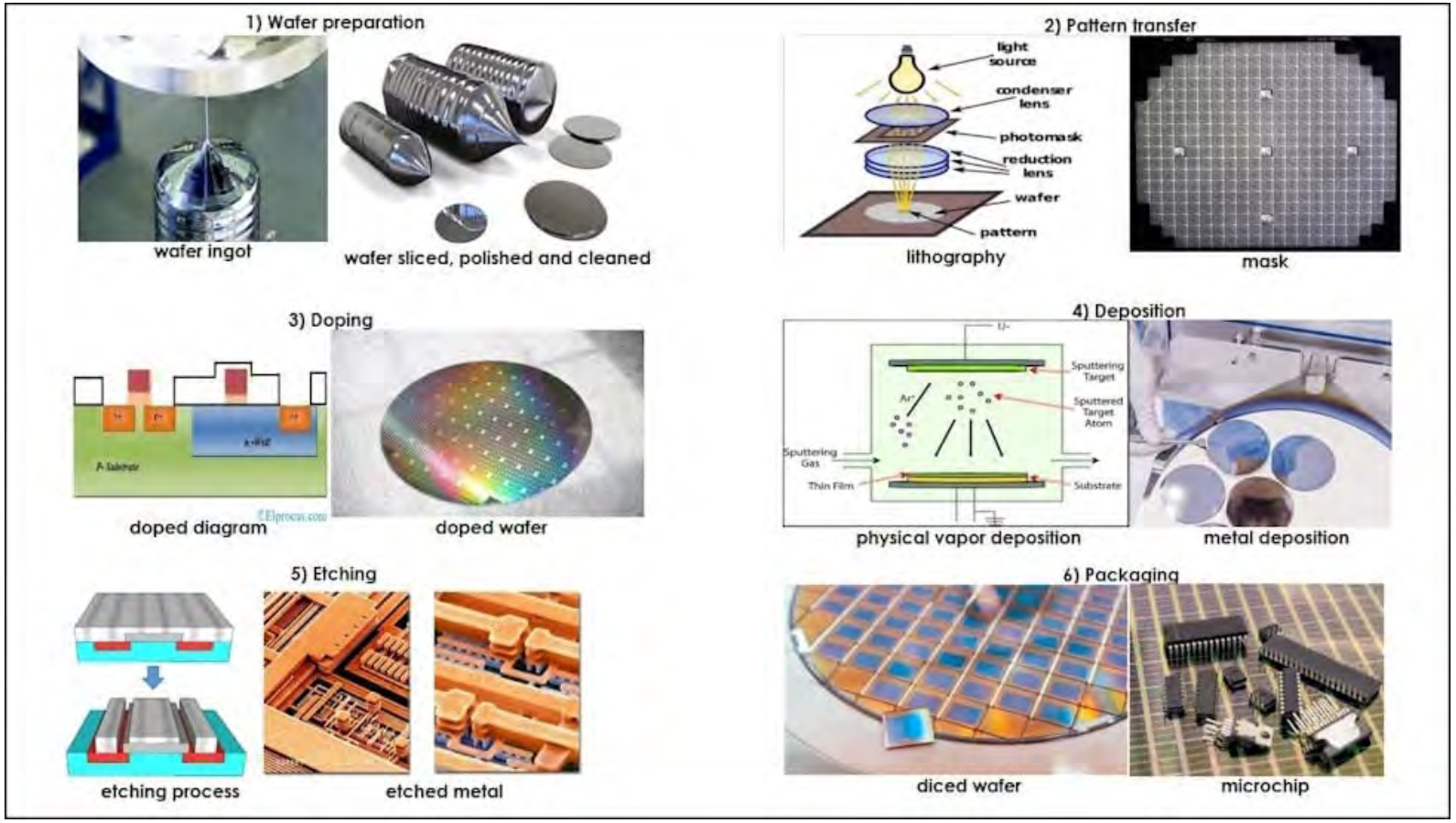
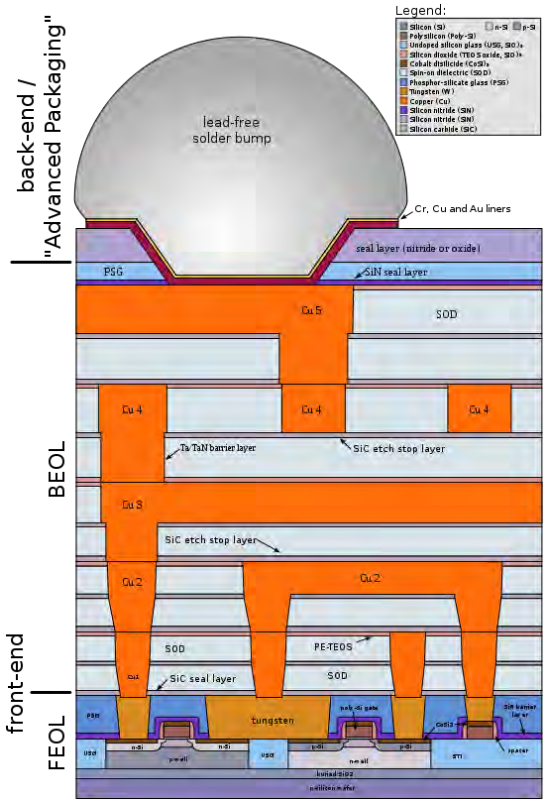


The right picture is the structure of 550px-Cmos-chip in 2000s



Reference : Semiconductor Device Manufacturing Process Challenges And Opportunities

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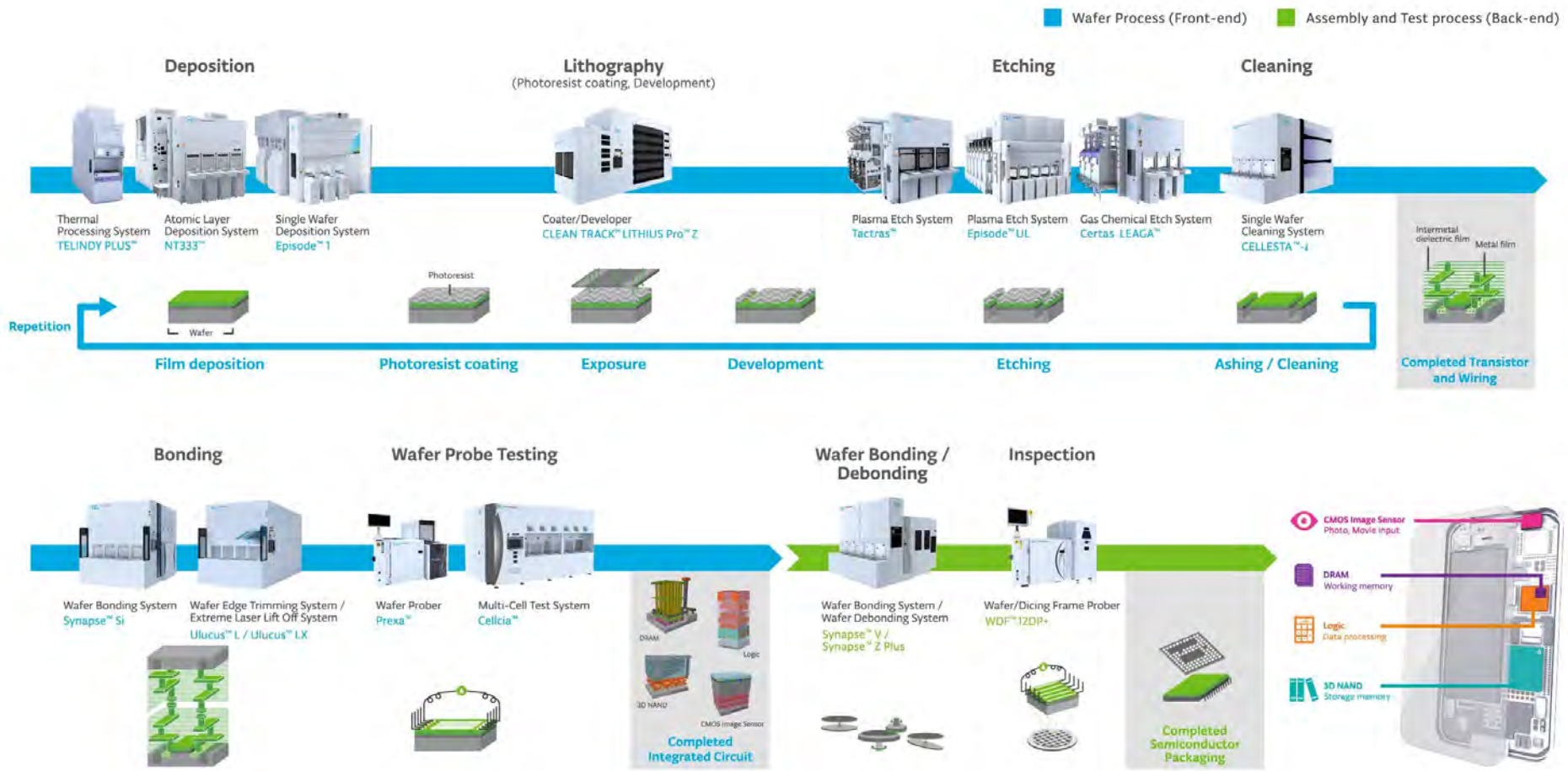
Steps involved in turning a Wafer into an Electronic Device

IC Chip fabrication Steps



Reference: Manufacturing Process | Products and Service(semiconductor production process) | Tokyo Electron Ltd. (tel.com)

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Typical Major Equipment

Wet bench



Rear Linear Automated Wet Bench | JST Manufacturing

Etching equipment



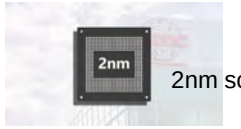
etching equipment semiconductor - Google Search

Lithography equipment



A Extreme Ultraviolet lithography (EUVL) scanner could cost in the region of c.USD150,000,000.
TWINSCAN EXE:5000 - EUV lithography systems | ASML

Latest trend
High Numerical Aperture NA Extreme Ultraviolet (High NA EUV) photolithography machines High NA EUV scanner – USD 370m – to provide even higher resolution/precision to make most advanced 3nm and 5nm chips



Reference: ASML

2nm scheduled to happen in the second half of 2026.

Ion Implanter



A modern ion implanter costs about $2–5 million

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3. Risks and Exposures – PML

Construction Costs

Figure 1: By the numbers: Potential costs of building a new leading edge fab



Source: Public information, Deloitte estimates
Representative numbers shown

*Advancements in Fab Technology and increased processing are expected to drive a 33%-66% increase in future fab costs.

https://www.bcg.com/publications/2023/navigating-the-semiconductor-manufacturing-costs

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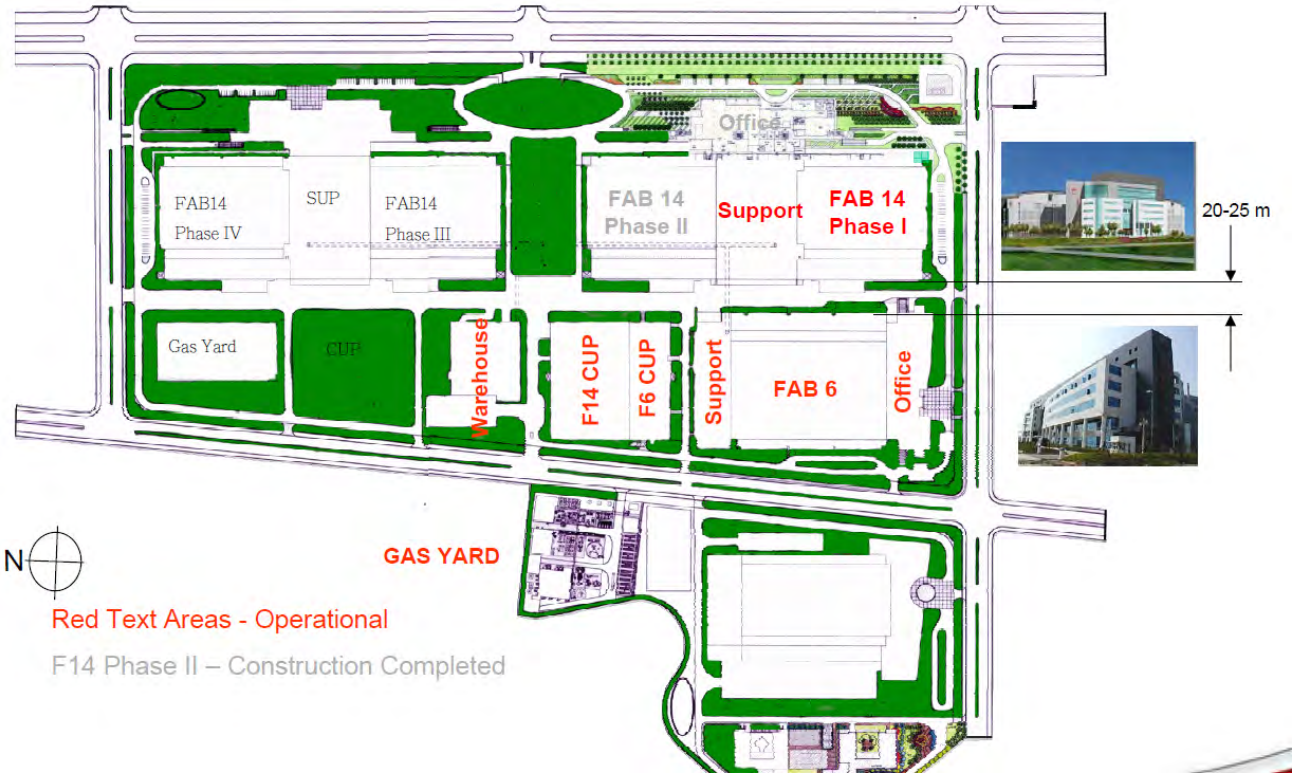
Outside view of a FAB Plant



Typical 5/6 Stories Building with offices, locker rooms, storage facilities, test & packaging rooms



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Typical Layout



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How clean is Cleanroom?

- ✓Urban Air – 35 mio particles per cu meter with size range 0.5 micrometers and bigger is considered equivalent to ISO 09 cleanroom
- ✓Rural Air – unlikely to find millions of particles per cubic meter. While the exact number varies depending on location and factors like dust storms or agricultural activities, studies suggest around 101 ± 47 particles per cubic meter (MP/m3) in rural areas.
- ✓A particle measuring only a millionth of a meter in diameter is big enough to bridge two electrical lines on a typical chip creating a short circuit.
- ✓ A room with 100,000 particles per cu meter is considered a Clean Room – Class 100,000 cleanroom (equivalent to an ISO Class 8 cleanroom), are commonly used in industries like manufacturing, where high levels of cleanliness are not strictly required,
- ✓ Advanced semiconductors require Clean Room of Class 10 (ISO 4) allows 10 particles of diameter 0.5 micrometers per cubic meter or Class 1 (ISO 1) allows 10 particles of diameter 0.1 micrometers per cubic meter
- ✓Other processes, such as chip packaging, may require a Class 10,000 (ISO 7) cleanroom.
- ✓Cost of a cleanroom: The cost of a Cleanroom depends heavily on the specific requirements. As a rule, prices are between 1,000 and 5,000 euros per square meter. What is a Cleanroom? - Schilling Engineering

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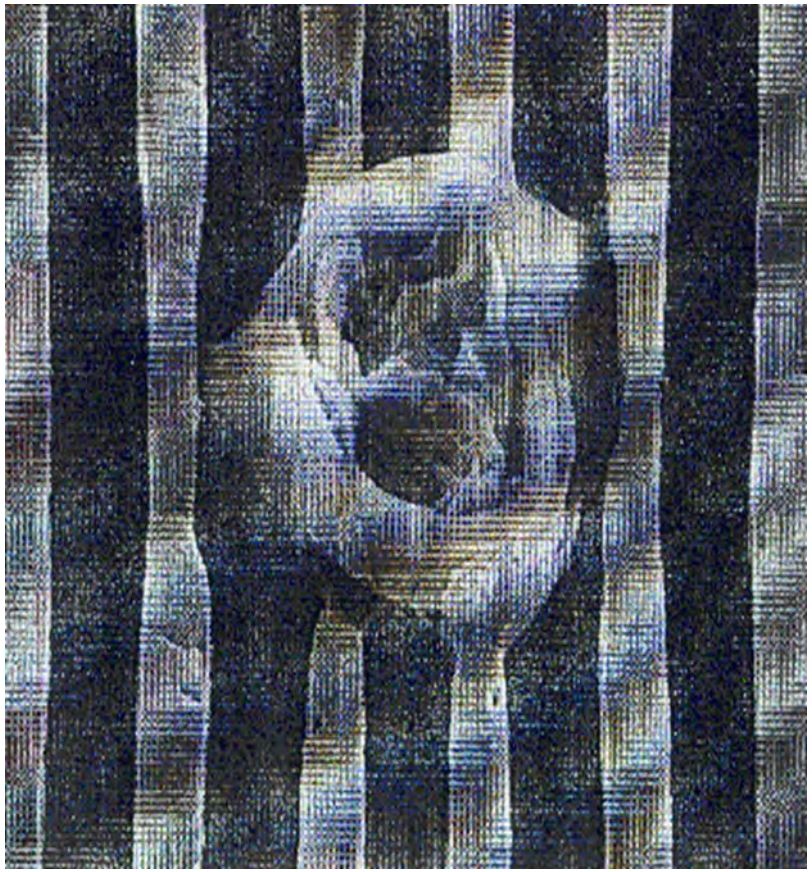
Why Cleanroom?



One dust particle of 0.5um (micron) can destroy a chip

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How BIG is big?

Example of Fab Building – clean room 8,000 m^2 floor area:

- Concrete for 25 km road
- 4,500km of reinforced steel bars
- 120km of Ultra clean pipe
- 250km of Electrical wires
- Single Silicon Wafer production use >1,000 kw/hr to make a single wafer
- A 200mm wafer has a surface area of about 31,400 square millimeters, while a 300mm wafer provides nearly 70,700 square millimeters, which means manufacturers can produce more dies per wafer.

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Main Hazards in a Fab

- ✓Flammable and explosive gases and liquids
- ✓toxic and corrosive chemical
- ✓Extreme value concentration
- ✓Combustible material
- ✓High temperature
- ✓High voltage
- ✓Particle contamination
- ✓Shock sensitivity

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Risks & Exposures

CAR and EAR

CAR – Buildings, Auxiliary Facilities

- Core & Shell - Cleanroom civil construction (Class 10 to Class 100 or ISO Class 3 to Class 4)

  − Typical factory building construction risks (meet NFPA and FM standards)

  − Contamination risks

  − Fire risks

  − Sandwiched panels

  − Hazardous Utilities



(Image credit: Miaoli Fire Department)

EAR –Transportation, Tools Move-in, Installation and Testing & Commissioning

- Fit out and Production equipment

  − Hazardous chemicals

  − Equipment movement

  − Equipment installation and Testing

  − Fire and smoke protection

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Risk Evaluation : Construction



Factors affecting Hazard Level:

- Fire and electrical hazards (combustibility of building construction materials & contents)
- Process safety risks (wet bench, stocker, in-process storage
- Hazardous chemicals such as Flammable, Toxic, Pyrophoric
- Separation & protection of hazardous processes / Chemicals
- High cost of clean equipment & environment - Fire separation of clean room spaces

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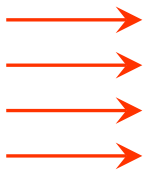
Fire Exposures

Clean rooms, heart of the FAB to produce semiconductor chips. A fire can cause a significant loss, as both the product and the machinery can be destroyed.

• Presents a challenge for standard fire protection due to the high velocity and movement of airflow.

• Different Protected Areas
- Wet benches
- Chemical Storage
- Production Tools
- HVAC Return Plenums
- Control Rooms



- **Air Sampling Smoke Detection (e.g. VESDA)**
- **Inert Gas Fire Suppression Systems (e.g. FM 200)**
- **Conventional Fire Detection and Control Systems**
- **Conventional Sprinkler Systems**

• Sources of Fire
- Short circuits
- Improper of handling heat sources
- Leaking of highly flammable, pyrophoric material

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Hazardous Chemicals

Several chemicals used in the semiconductor manufacturing process are indeed hazardous and/or flammable. Here are a few examples:

- **Silane (SiH4):** used for silicon deposition, highly flammable and reactive. It can ignite spontaneously in air and react with oxidizing agents.
- **Sulfur Hexafluoride (SF6):** not flammable and used for etching is a potent greenhouse gas and needs to be handled with care due to its impact on the environment.
- **Hydrofluoric Acid (HF):** a very dangerous chemical, not flammable but highly corrosive and toxic. It can cause severe burns and is harmful if inhaled, ingested, or comes into contact with the skin.
- **Phosphine (PH3):** Used as a dopant for n-type semiconductors, this gas is both flammable and toxic.
- **Arsine (AsH3):** This is another toxic and flammable gas used as a dopant.
- **Acetone and Isopropyl Alcohol (IPA):** common solvents are flammable.

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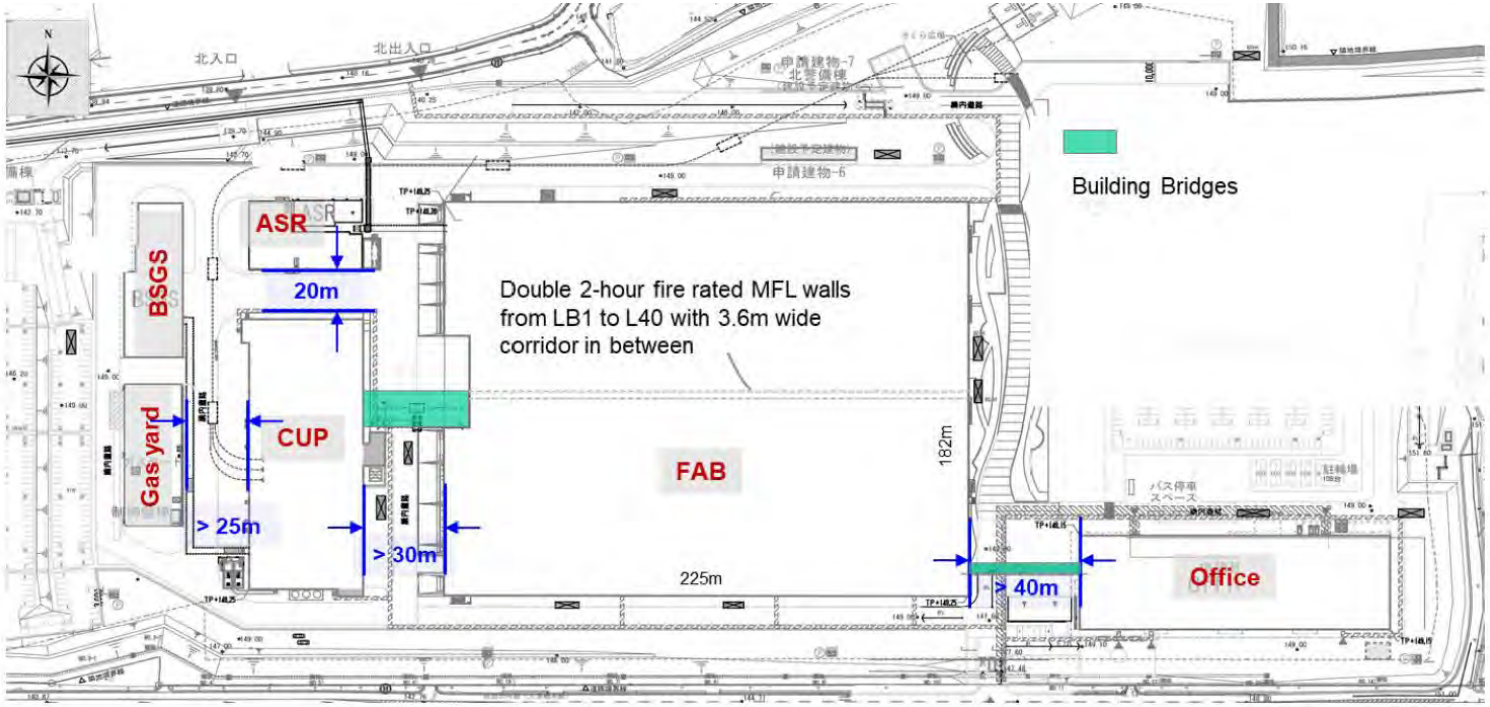
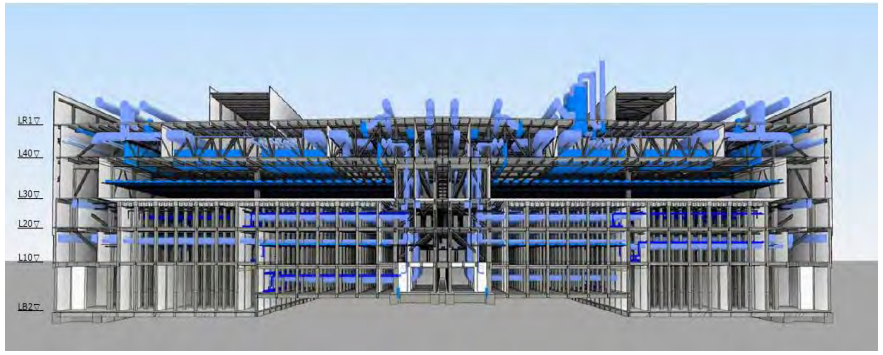
Fire Wall Separation



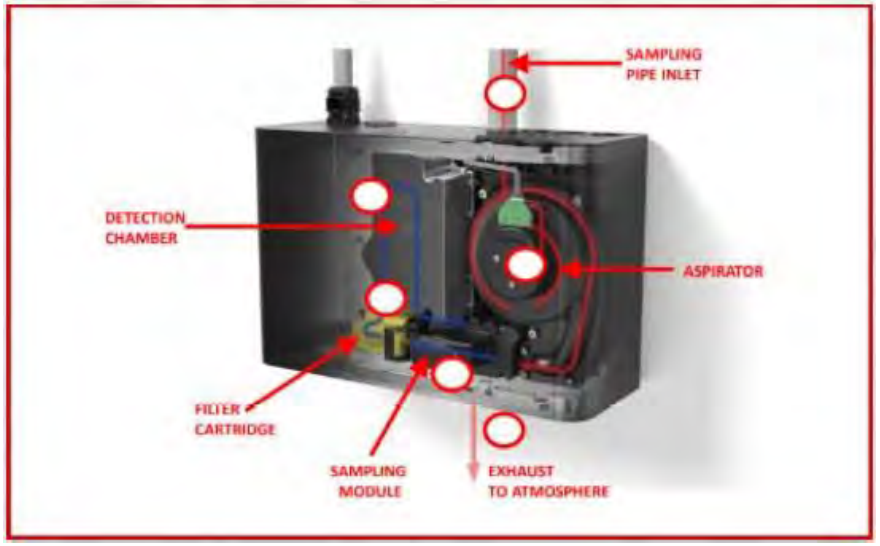


Typical BIM of a FAB

Fire Fighting System
VESDA –Very Early Smoke Detection Apparatus



https://www.wifgas.com/thermal-meter



https://www.fireengineers.in/services/vesda-smoke-detection-system/

- For semiconductor industry, the ERT may only have < 3 mins to response
- Continuous air sampling provide the earliest possible warning for a potential fire
- Critical time needed to investigate, intervene and avoid business disruption
- Filtered air will enter a detection chamber exposed to a laser source

Fire Protection
ERT





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Exposures and Protections

Earthquake Exposures

- Shake damages (Building, Storage, Equipment)
- Fire after earthquake
- Water damage after earthquake





Cable Crossing Sealing Protection – Able to maintain air-tightness



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Construction & Erection – PML assessment

- Smoke and fire detection systems and sprinklers are often not operational
- Cable and pipe ducts are not properly sealed
- Expensive and highly sensitive equipment
- Erection works performed in the vicinity of operating production lines
- The coordination of many specialized subcontractors

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PML Estimation (without adequate protections)

Material Damage:

- Premises are generally divided into Main Fab Building and Utility Building
- Main insured value is the Main Fab Building
- Production tools / facility highly susceptible to smoke/heat and water damage
- PML = 100% of Main Fab Building



Delay in Start Up (DSU) / ALOP / Business Interruption (Operation)

- Plant reinstatement period >18 months or longer
- Always take 100% of DSU TSI
- *WIP (Work in Progress) – can significantly higher than material damage (more concern on Operational risk)*

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Key Conditions



- ***Fire Fighting Facilities Clause***

  − Swiss Re EPI 61 – Fire Protection at Semiconductor Plant Projects (2007)
  − Swiss Re EPI 62 - Handover of Semiconductor Plant Projects (2007)
  − Typical Fire Fighting Facilities Clause (includes ERT availability around the clock)

- ***Testing and Commissioning*** *– Hand-over Schedule (next slide)*

- ***Key Features***

  − Fire Fighting System are fully tested, certified and activated before equipment moved-in
  − Smoke Detection Systems (e.g. VESDA, HSSD)
  − Emergency Response Team(ERT)(stand-by 24 hours)
  − Handover Schedule (typical 90 days to 120 days with max limit) - Trend on getting longer and longer on Testing and Commissioning Period exceeding 180 days and may reach 360 days

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Testing & Commissioning

- ESO (Equipment Sign-Off) programme in place
- Sprinkler systems fully operational
- Weekly inspection
- EATR (Equipment Acceptance Testing Record)
- Hand Over

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Placement Strategy



- Combined CAR and EAR
- CAR (Shell Building) and EAR (Equipment Moved-In) placed separately
- DSU is not normally considered
- Usually, CAR for Shell buildings are arranged by Contractors, and Tools Move-In by Owners
- Limits of Liability are a feature due to the very large TSI involved

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4. Loss Experience

Loss Examples

- Winbond Fire (1996) – during installation of a Chemical Vapour Deposition (CVD) Machine, generated a lot of smoke and corrosive gases – loss settled USD 180m (55% Property / 45% Construction). *Today's value, loss amount easily double.*



- UICC(1997) - Fire during repair work on polypropylene pipes spreading to other areas and floors via the exhaust ventilation system – USD 350m (75% Property and 25% construction)



- Dropping of stepper machine during installation – value of machine USD 5m – incurred USD 200k for returning to original manufacturer for repairing and re-adjustment

- Flood at basement facilities – USD 19m PD + BI

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Loss Examples

- Earthquake in Taiwan Feb 2016 (6.4 Richter scale) Pingtung City - USD 230m (excluding BI) – **Operational**



- Taiwan Earthquake 2024 - **Operational**
  - TSMC - initial reported claim - USD 600m (significant loss from WIP)
  - Micron–initial reported claim - USD 150m
  - Powerchip
  - Etc…



Loss Examples

Advanced Semiconductor Engineering Inc. Taiwan (DOL : 1 May 2005 Sun) –- **Operational**

• Packaging and Testing Facility in Taiwan USD250m PD loss (fire originating in boiler room ignites a plastic exhaust ducts and spread all floors at a 11-storey packaging and test facility



SK Hynix (Wuxi Plant in China) (DOL Aug 2013) - **Operational**

• Additional process gas lines installed
• Contractor mixed up nitrogen and hydrogen to a VMB
• Explosion occurred a week later, fire spread through exhaust ductworks
• PD/BI loss - > USD 900m



Source: ChipHell Forums

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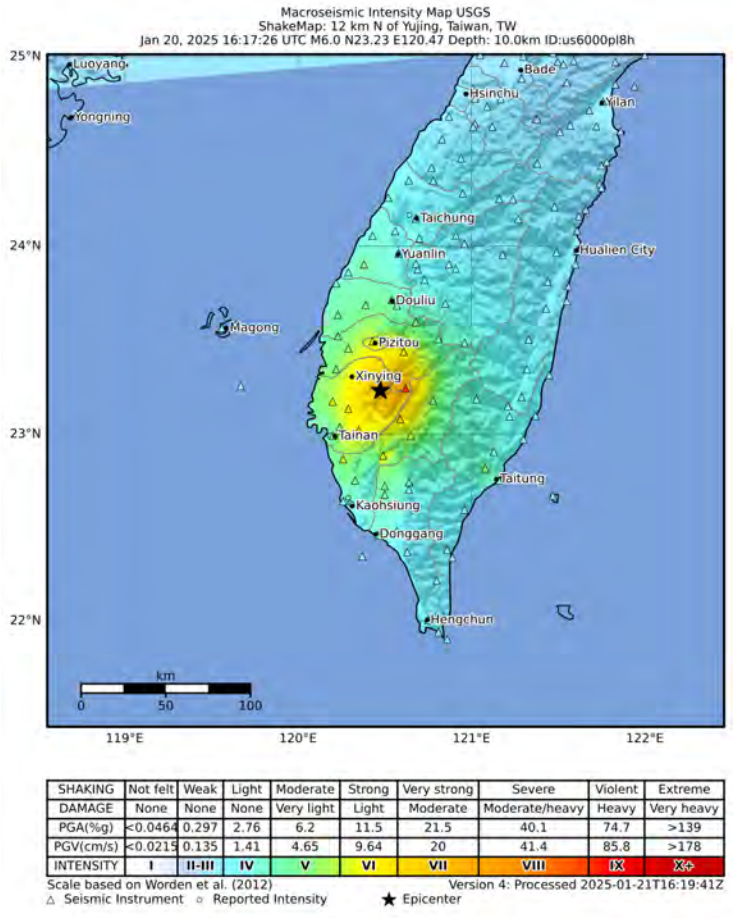
Loss Examples
Jan 2025 Various EQ

- Mag. 6.4 earthquake - 44 km northeast of Tainan, Taiwan, Jan 2025 - USD 470m – **Operational**

Affected were Building / Machinery / WIP (Wafers) / Indirect Material



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5. Outlook

Outlook - Global

Global Semiconductor Demand Forecast:

✓Global semiconductor industry sales expanded +19 % to $627 billion in 2024. It is estimated to reach the all-time high at US$697 billion in 2025 marking an 11% year-over-year increase. Asia Pacific and the Americas regions are anticipated to sustain their double-growth (World Semicon Trade Stats)

✓Industry projected to achieve $1 trillion in global revenue by 2030. (KPMG, McKinsey)

✓About 70% of growth predicted to be driven by automotive, data storage, and wireless industries. (McKinsey)

✓AI is driving further demand, especially on the high-end chips

Challenges on the Supply Chain:

✓Imbalances between supply and demand

✓Customer specifications (wide variety of applications and functionality requirements)

✓Complexity of the global supply chain (raw materials, design, manufacturing, assembly / testing to sales)

✓Regulation of materials

✓Talent shortage

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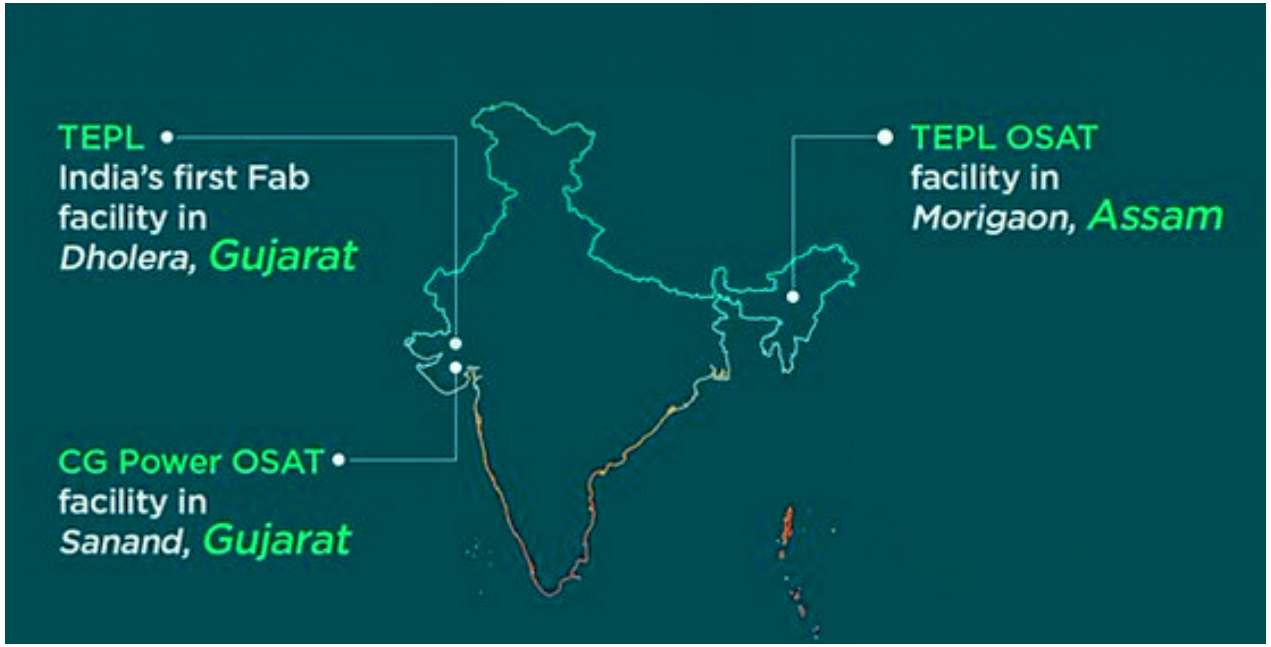
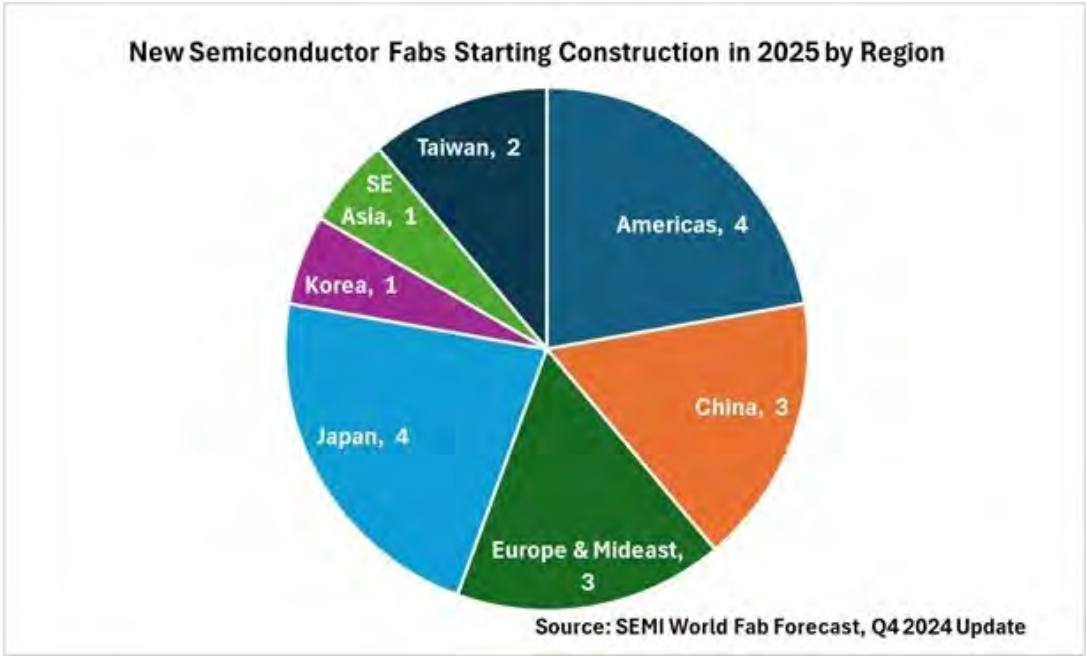
Outlook – India / Global

[India's Semiconductor Sector: Three New Plants Get Approved] – 1 FAB and 2 OSAT



Source: Government of India

Global



TSMC aims to produce next-generation 1.4-nm chips by 2028 - Nikkei Asia

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India - First Fab Plant

Tata’s US$11 Billion Leap: India’s First Semiconductor Fab in Partnership with Taiwan’s PSMC – March/Sept 2024

*Tata Electronics and PSMC to build India’s first 12-inch wafer semiconductor f**ab, project aim to start end of 2026.** The fab will produce chips for AI, automotive, computing, data storage, and wireless communication applications*.
The US$11 billion project, backed by India's Semiconductor Mission (ISM), is heavily subsidized, with 50% of the funding coming from India's central government and an additional 20% from local governments. The 12-inch wafer fab will utilize 28nm processing technology

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Outlook

Indian semiconductor market reached a value of US$34.3 billion in 2023 and is projected to attain US$100.2 billion by 2032, exhibiting a compound annual growth rate (CAGR) of 20.1 percent during the forecast period spanning from 2023 to 2032.

With the growing popularity and production of **electric vehicles (EVs) in India**, it is projected that semiconductor use in fields including safety, electrification, communication, and networking would rise. These units, which prioritize developing job prospects and strengthening chip design strengths, have the potential to completely transform the semiconductor industry.

India's enhanced allocation in the interim budget, together with its collaboration with US manufacturing giant Micron and the establishment of three new manufacturing facilities, highlight its commitment to becoming a leading manufacturer of semiconductor chips.

To realize its goal of becoming a significant player in the global semiconductor value chain, India needs to continue wooing high-tech investors and facilitate a pro-R&D environment – offering consistent and transparent financial and tax support as well as encouraging the cultivation of homegrown talents.

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Interesting Videos and Links



- The Semiconductor Terms That You Must Know | 'All About Semiconductor' by Samsung Semiconductor (youtube.com)
- ‘Semiconductor Manufacturing Process’ Explained | 'All About Semiconductor' by Samsung Semiconductor –YouTube
- #300mm Silicon #Wafer Manufacturing Process (youtube.com)
- Navigating the Costly Economics of Chip Making | BCG
- Tooling up the CHIPS Act | Deloitte US
- #300mm Silicon #Wafer Manufacturing Process (youtube.com)

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Q & A



Thank You

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Mumbai, 26th May 2025

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