

Understanding Semiconductor Lead Times

PCB Carolinas 2022

Note regarding material

- The following information is meant for educational purposes only and does not imply any official statement or position from Arrow Electronics. Certain generalizations have been made to simplify and/or clarify broader points. When specific industry data has been used, credit has been given to the source of that information. Other data points beyond those come with the understanding as not having originating from actual industry research.

Goal

- To provide insight into the market dynamics that impact the availability and Lead times of semiconductor products. Additionally, to explore the global nature of how Semiconductor devices are fabricated Packaged and Tested.

Agenda

- 1) Understanding How Semiconductors are made
- 2) The impact of surging demand on a constrained Fab resources

Where are Semiconductors made?

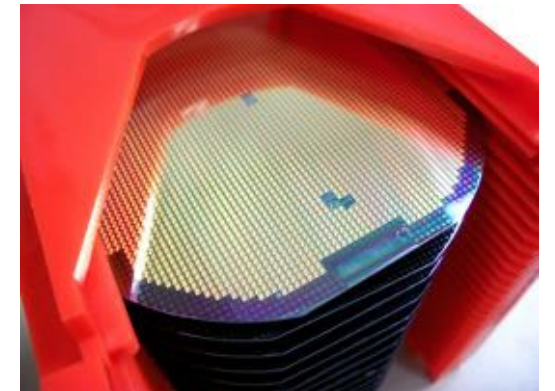
- In Facilities known as Fabrication Facilities most often called FABs



- A Modern FAB costs approximately \$3-12B US to build. Also 24+ Months to construct
- Inside the process areas the air is 1000 times cleaner than most operating rooms

What do we mean a “Wafer Fabrication”

– Raw unprocessed wafers go in



– Finished wafers come out ready to be cut or “Diced”.

How Long Does the Manufacturing Process Take?

– Determines Lead-time



How Long Does the Manufacturing Process Take?

- Determines Lead-time



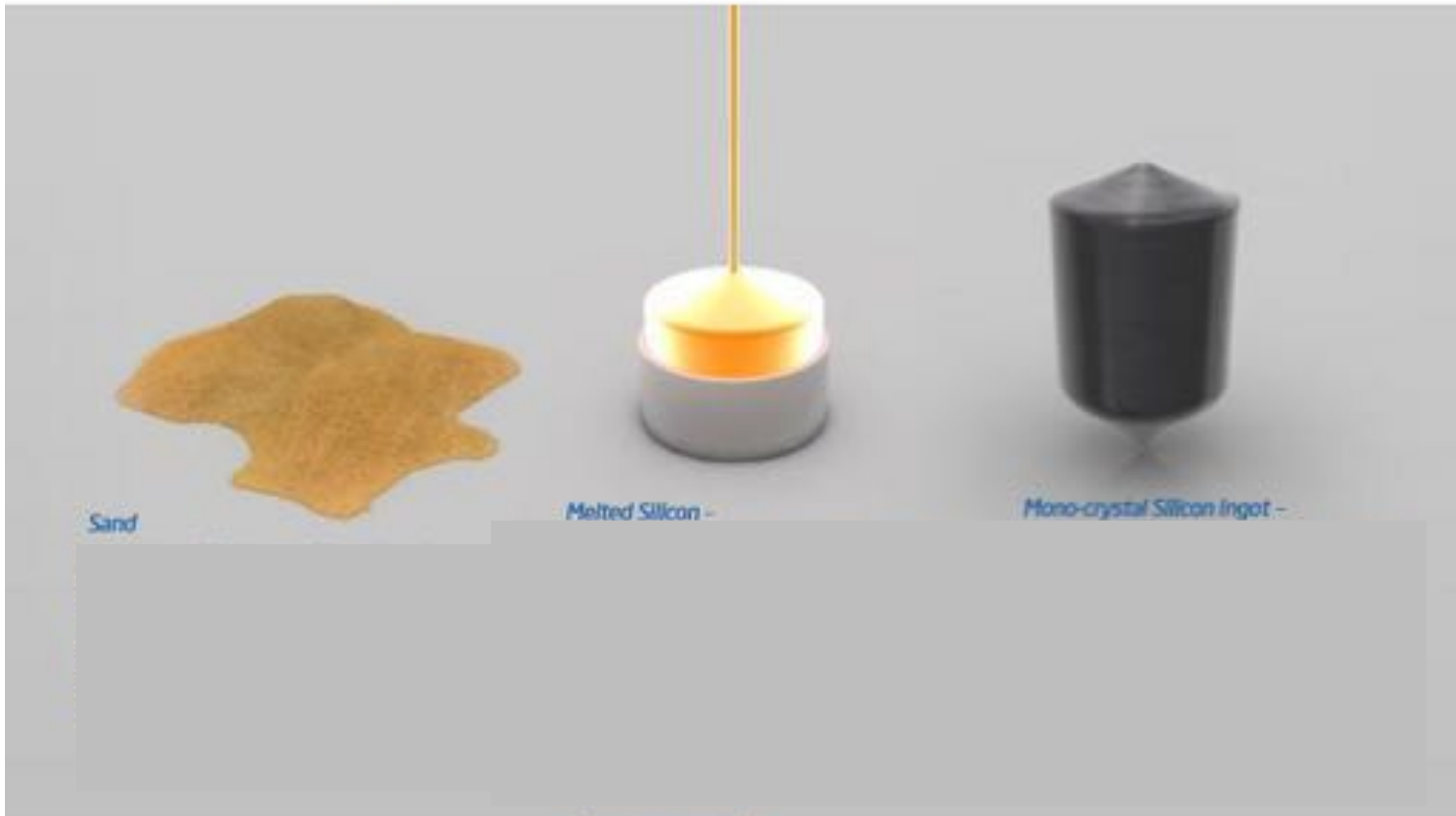
Recent spikes in Demand have pushed out Lead times to unprecedented lengths

How Long Does the Manufacturing Process Take?

- Determines Lead-time

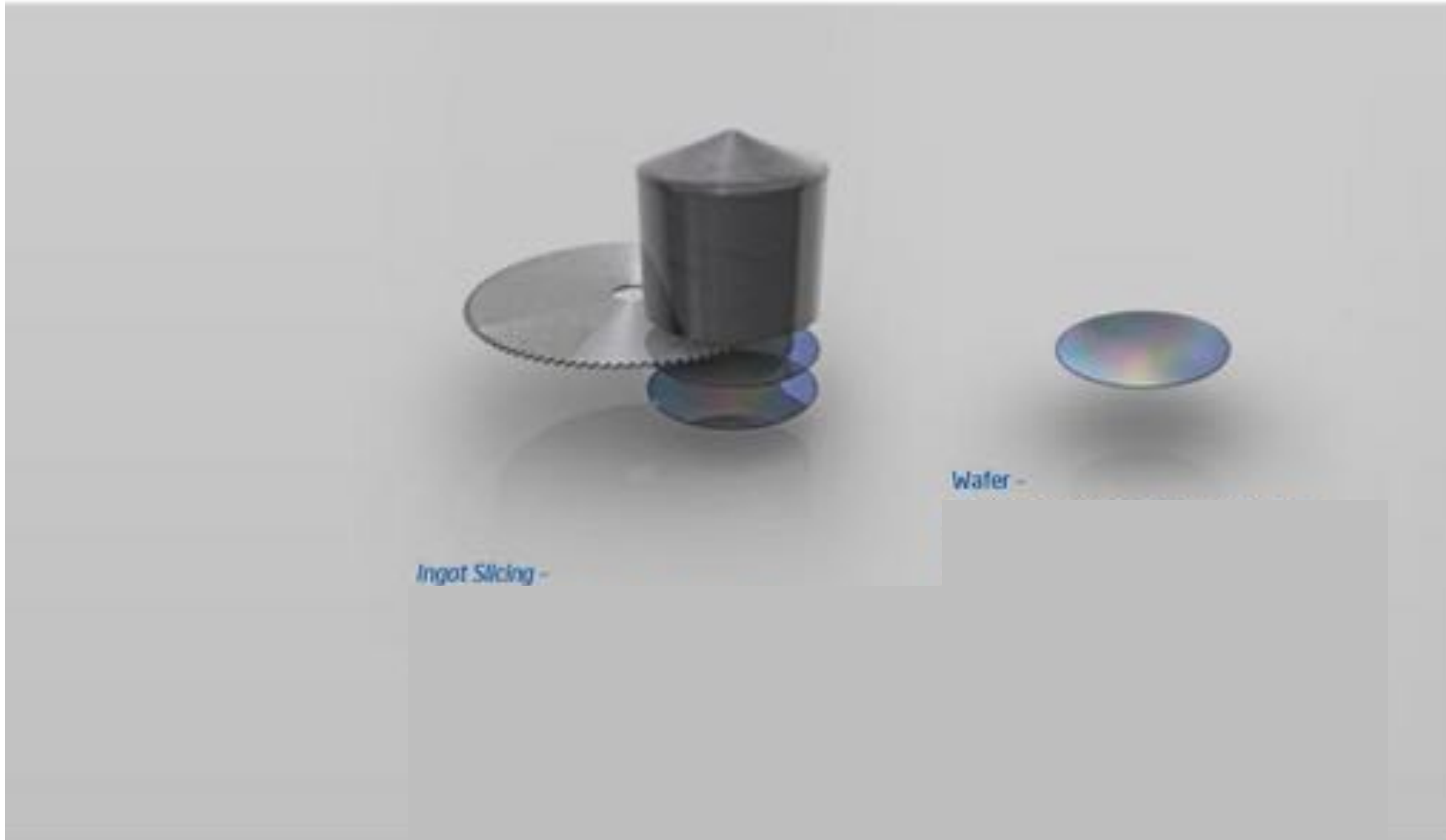


Sand / Ingot



Copyright © 2009, Intel Corporation. All rights reserved.
Intel, Intel logo and Intel Core are trademarks of Intel Corporation in the U.S. and other countries.

Ingot / Wafer



Copyright © 2009, Intel Corporation. All rights reserved.
Intel, Intel logo and Intel Core are trademarks of Intel Corporation in the U.S. and other countries.

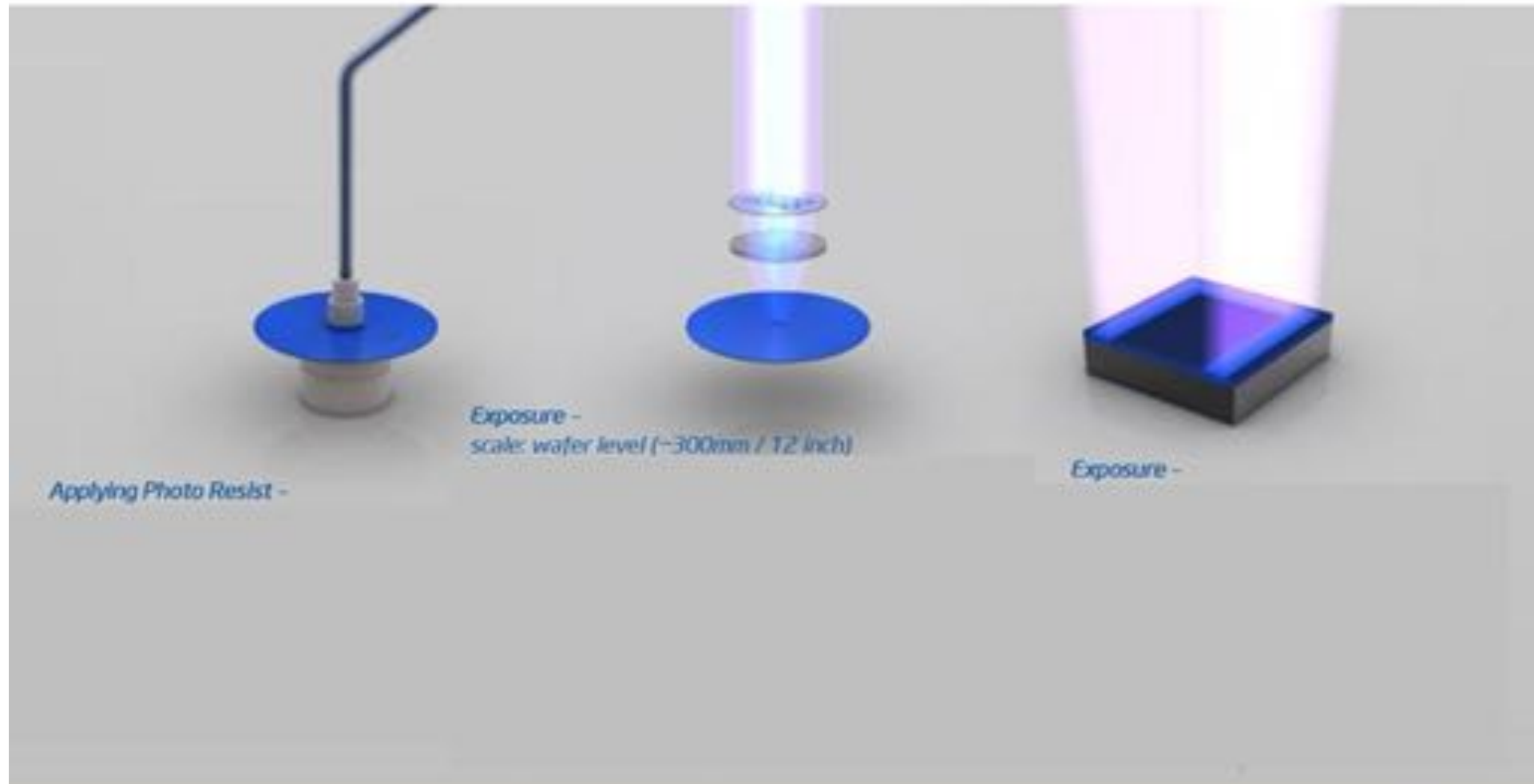


How Long Does the Manufacturing Process Take?

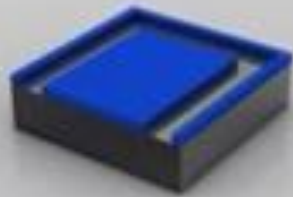
- Determines Lead-time



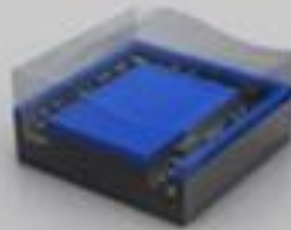
Photo Lithography



Etching



Washing off of Photo Resist -

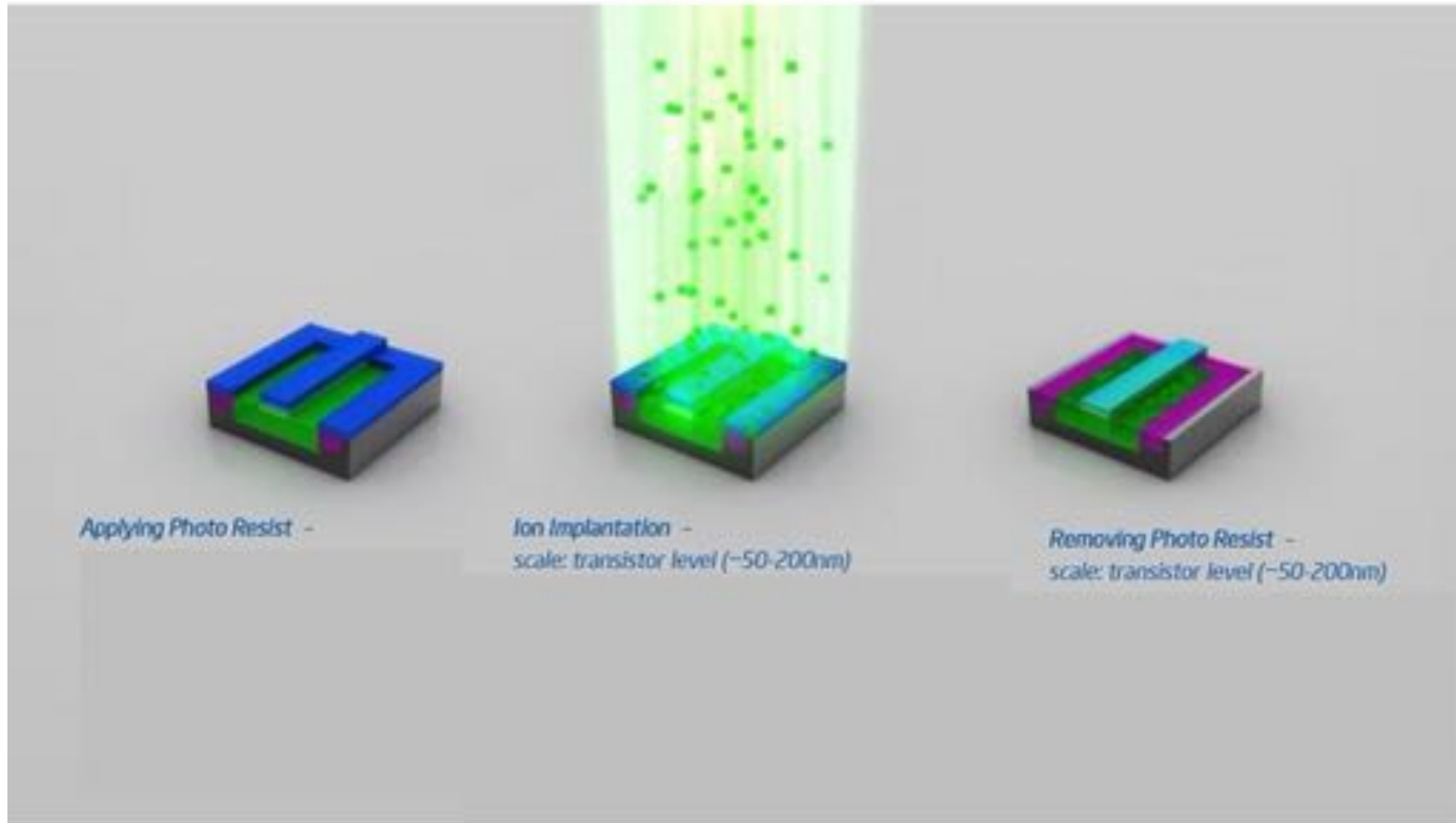


Etching -



*Removing Photo Resist -
scale: transistor level (~50-200nm)*

Ion Implantation



Metal Deposition

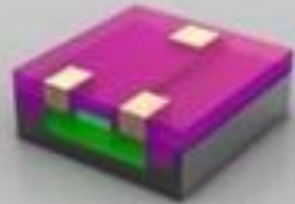


Ready Transistor -

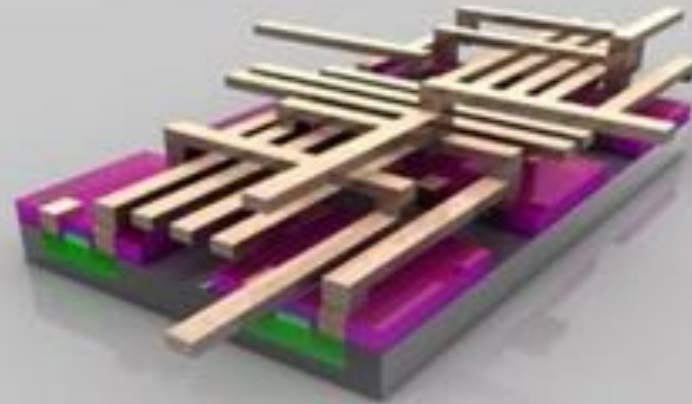
Electroplating -

After Electroplating -

Metal Layers



Polishing -



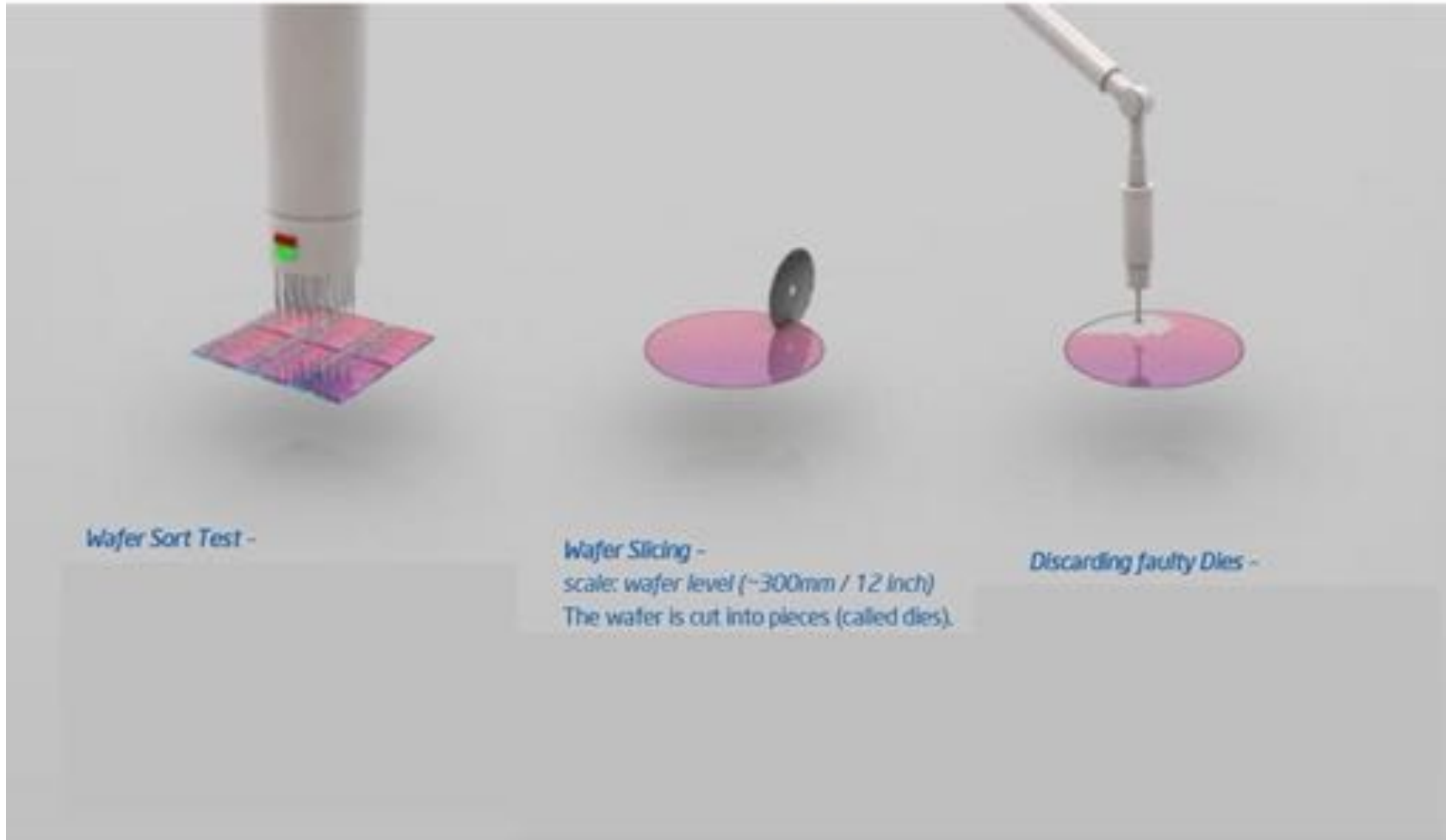
Metal Layers - scale: transistor level (six transistors combined ~500nm)

How Long Does the Manufacturing Process Take?

– Determines Lead-time



Wafer Sort Test / Slicing



Copyright © 2009, Intel Corporation. All rights reserved.
Intel, Intel logo and Intel Core are trademarks of Intel Corporation in the U.S. and other countries.



How Long Does the Manufacturing Process Take?

- Determines Lead-time



Packaging



Individual Die -

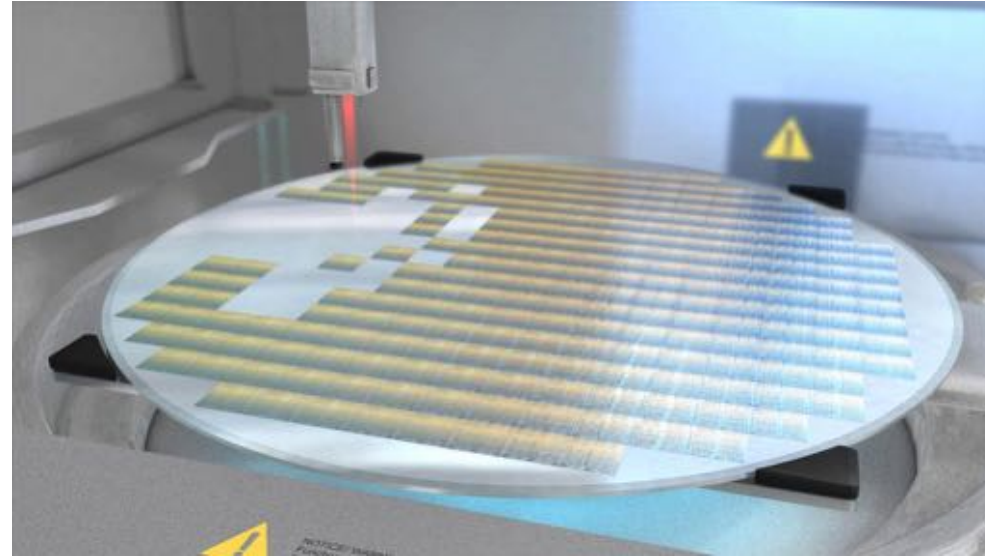
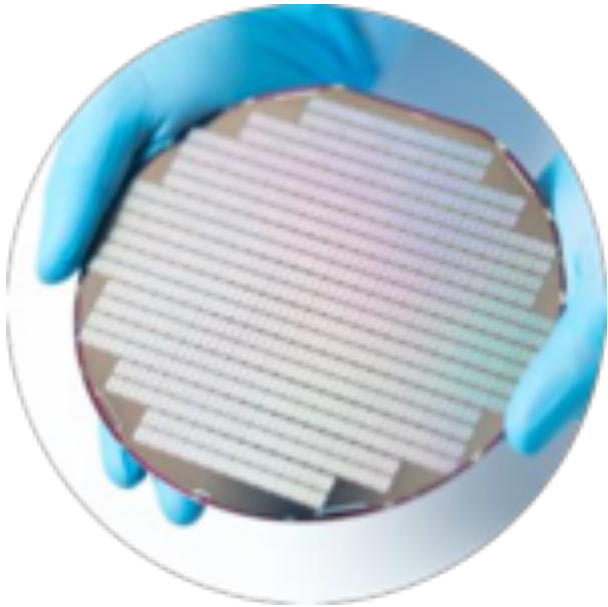


Packaging -



Processor -

Semiconductor Packaging



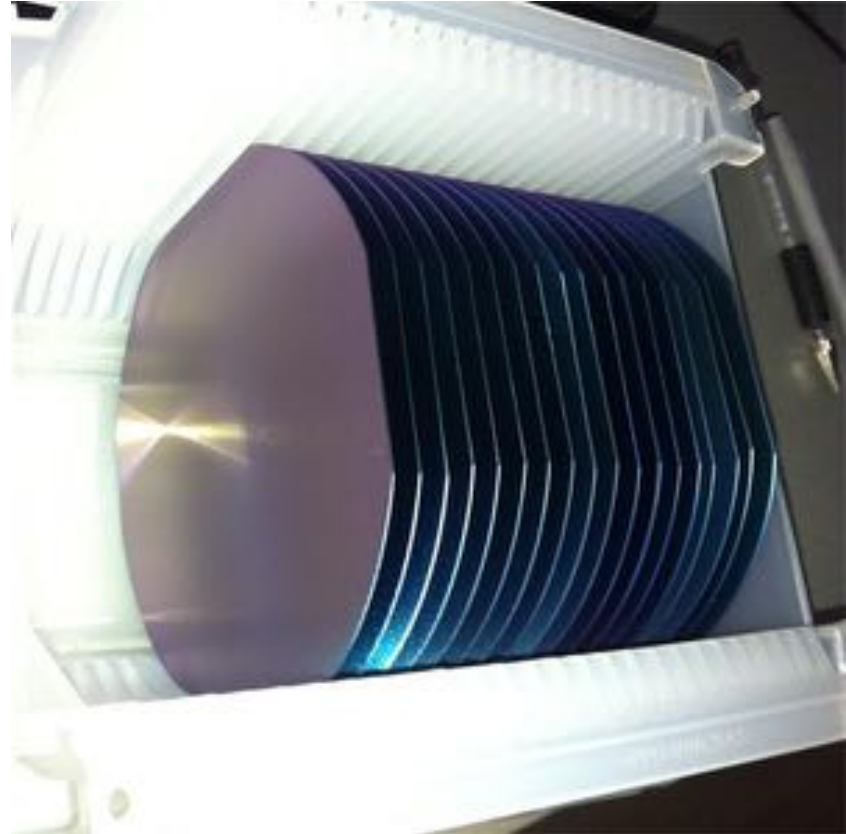
Individual wafers are then ‘Diced’ into individual “Die” that are then placed on a metal “leadframe” and then hermetically sealed into a Plastic (or similar) “Package”

Wire Bonding the die to a package

- [ASM Eagle 60 video 1 OK - YouTube](#)

What is a “Boat” of wafers

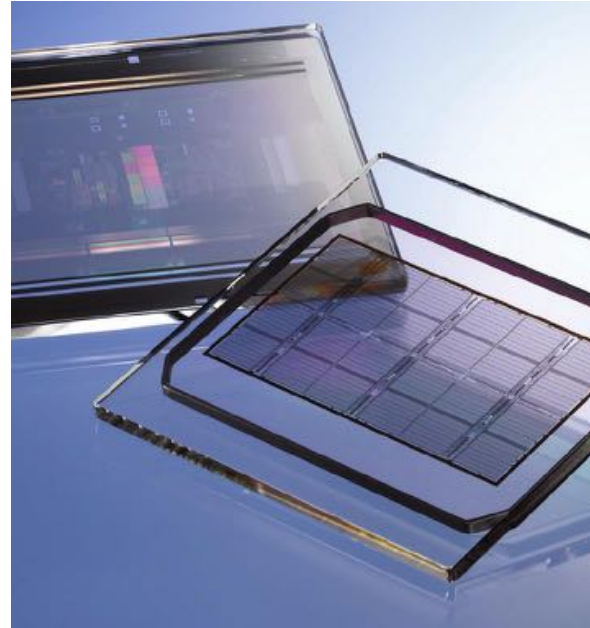
- Typically, 10-25 wafers of identical die processed at the same time with the same mask set*
- So say we get 5000 die per wafer x 20 wafers = **100K units**
- Although the die may be the same it is possible, even likely, they will be used across dozens of different final part numbers.



- * A Mask Set is a series of Stencils that allow the specific patterns of transistors to be etched into the Silicon Substrate through a process called photo-lithography.

What are Masks

- A Mask defines the pattern of Light that is allowed to fall upon the silicon substrate that has been coated with Photoresist.
- Allows multiple exact copies of the die to be produced on a single wafer.



https://www.researchgate.net/figure/Two-photomasks-with-pellicles-The-upper-mask-is-a-conventional-binary-intensity-mask_fig1_234146446

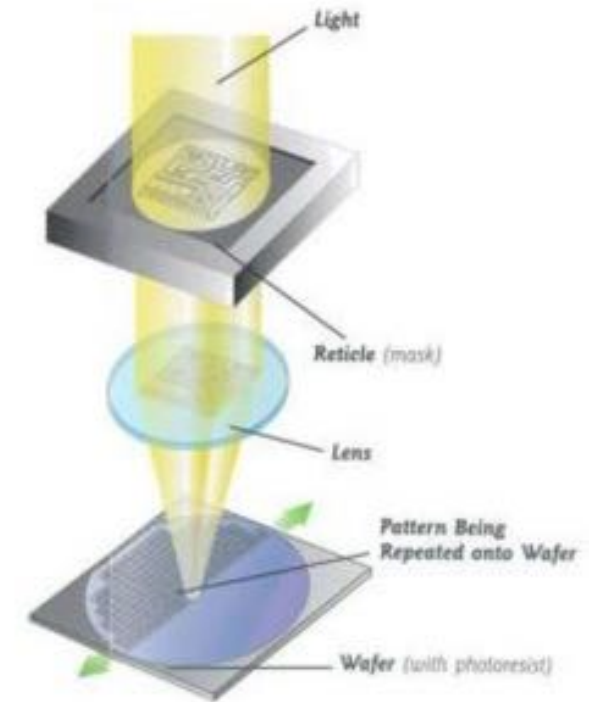


Figure 1 from THE USE OF EUV LITHOGRAPHY IN CONSUMER MICROCHIP MANUFACTURING | Semantic Scholar

Example of Multiple different parts using the same “Mask Set”

PLANNER	CPN	MASK	FINISHED_GOODS_ DCLASS	TIME_STAMP	Core	CPU Speed (MHz)	Flash (K)	Package	Temp Grade	T&R
KM	ATSAMD21E15C-UUT	661A7	30,000	1/16/2022	Cortex-M0+	48	32	45 WLCSP	Industrial (85°C)	T&R
KM	ATSAMDA1G16B-MBT	661A7	12,549	1/16/2022	Cortex-M0+	48	64	48 QFN (7x7)	Automotive Grade 2 (105°C)	T&R
KM	ATSAMDA1E14B-MBT	661A7	11,092	1/16/2022	Cortex-M0+	48	16	32 VQFN (5x5)	Automotive Grade 2 (105°C)	T&R
KM	ATSAMD21J16B-AFT	661A7	10,500	1/16/2022	Cortex-M0+	48	64	64 TQFP (10x10)	Extended (125°C)	T&R

So, What is the “Hold up”?

- There are hundreds of steps involved in making silicon wafers.
- Boats of Wafers can only be done sequentially
- Meaning if a lot of “Boats” are waiting to move through the fab, they can’t start until an available spot is open.



- It is analogous to moving a ship through a canal with dozens of locks.
- The next “Boat” can’t move into the next lock (or fab station) until the last Boat has cleared that same lock.

Unfortunately, today, We have dozens of suppliers waiting on their fab starts



Global footprint of World Semiconductor manufacturing

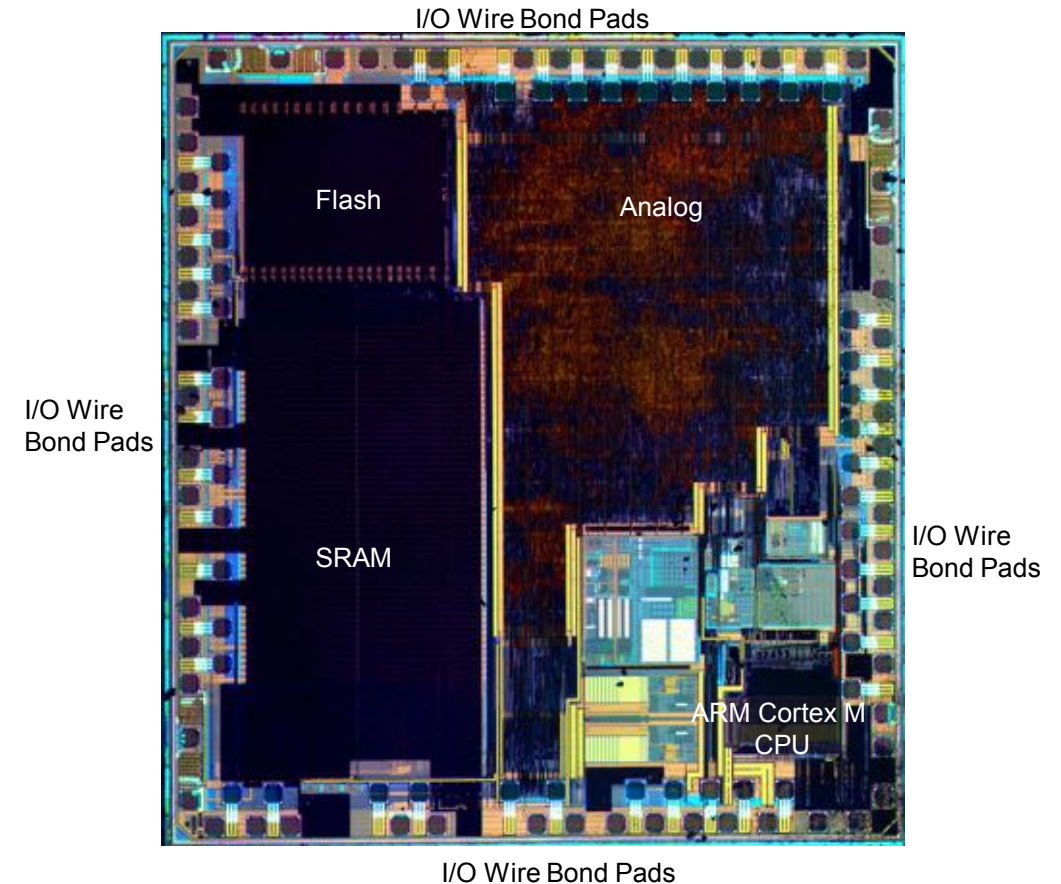
– Determines Lead-time



Ongoing Covid response regulations differ by nation so add uncertainty to supply chain

Why have Microcontrollers been so Hard Hit

- Microcontrollers use various building blocks of mixed technology types including Digital Processors, Analog Static RAM memory and Flash Memory
- Common Building Blocks of IP (intellectual Property)
- Can only be built on their designated geometry process (i.e. 90 nm, 60nm, etc)
- The past decade has concentrated the “Fabrication” of these devices into a few common fabs, namely TSMC, Global Foundries and a few others



<https://en.wikipedia.org/wiki/STM32#/media/File:STM32F100C4T6B-HD.jpg>

The impact of Geometry –90nm vs 60nm vs 40nm

- Semiconductor wafers are processed at a particular fixed geometry
- Although a Fab may support various geometries, they must run the wafer on the line of the designed geometry
- A fab may have more availability on a smaller (newer) geometry while larger lines are more tightly constrained.



As a reference the diameter of a Human hair is approximately 75,000 nm

What is Global Wafer Start Capacity = ~250 Million Wafers annually

Worldwide Wafer Capacity Leaders

(Monthly Installed Capacity in Dec 2020, 200mm-equivalents)

2020 Rank	2019 Rank	Company	Headquarters Region	Dec 2019 Capacity (K w/m)	Dec 2020 Capacity (K w/m)	Yr/Yr Change	Share of Worldwide Total	Inclusion or Exclusion of Capacity Shares from JV Fabs
1	1	Samsung*	South Korea	2,935	3,060	4%	14.7%	
2	2	TSMC	Taiwan	2,505	2,719	9%	13.1%	+ shares of SSMC & VIS
3	3	Micron	North America	1,841	1,931	5%	9.3%	
4	4	SK Hynix	South Korea	1,743	1,878	8%	9.0%	
5	5	Kioxia/WD	Japan	1,406	1,598	14%	7.7%	

*Line 13 partially excluded in 2020 due to conversion to image sensors.

Source: Companies, IC Insights' Global Wafer Capacity 2021-2025 Report

The top 5 Semiconductor Fab companies supply about 54% of the world's wafer starts

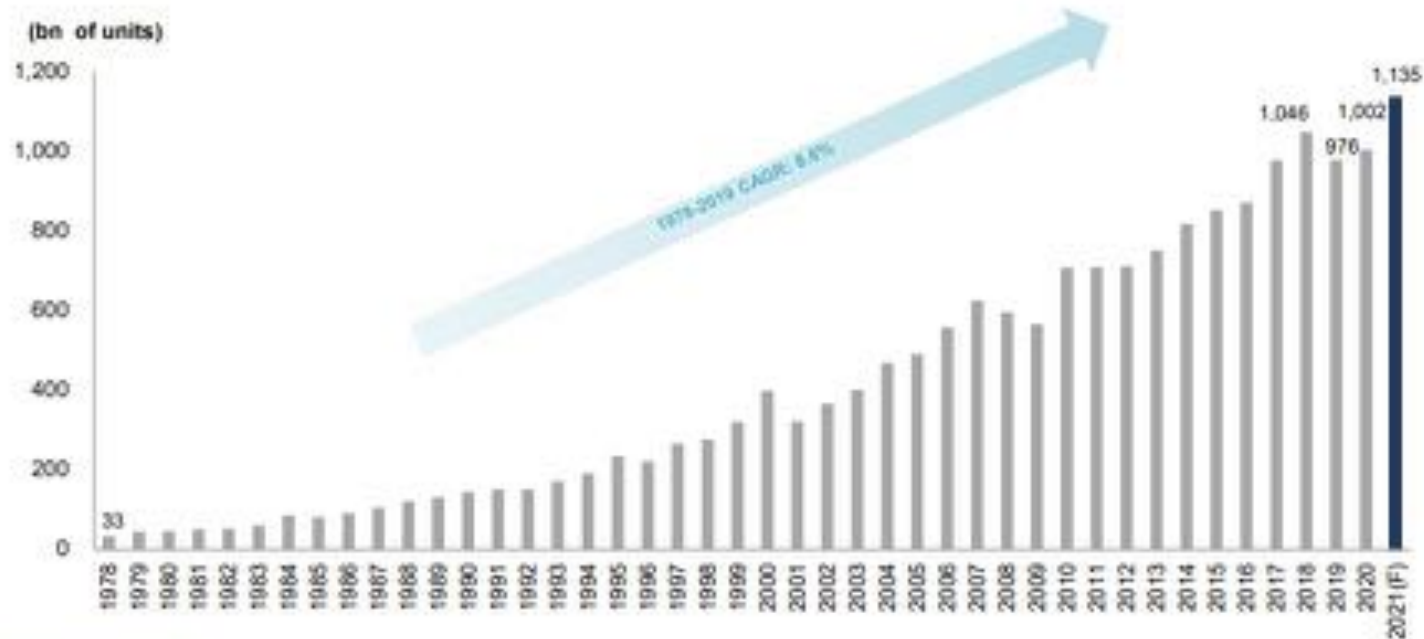
What is Global Wafer Start Capacity



Semiconductor Unit Shipment

- Total semiconductor unit shipments are forecast to rise 13% in 2021, to 1,135 bn, setting a new all-time annual record and marks the third time that surpassed one trillion units in a calendar year.

Tracking Semiconductor Unit Growth



Source: IC Insights, April 2021

Note: Shipment includes IC, optoelectronics, sensor/actuator, and discrete (D-S-D) device

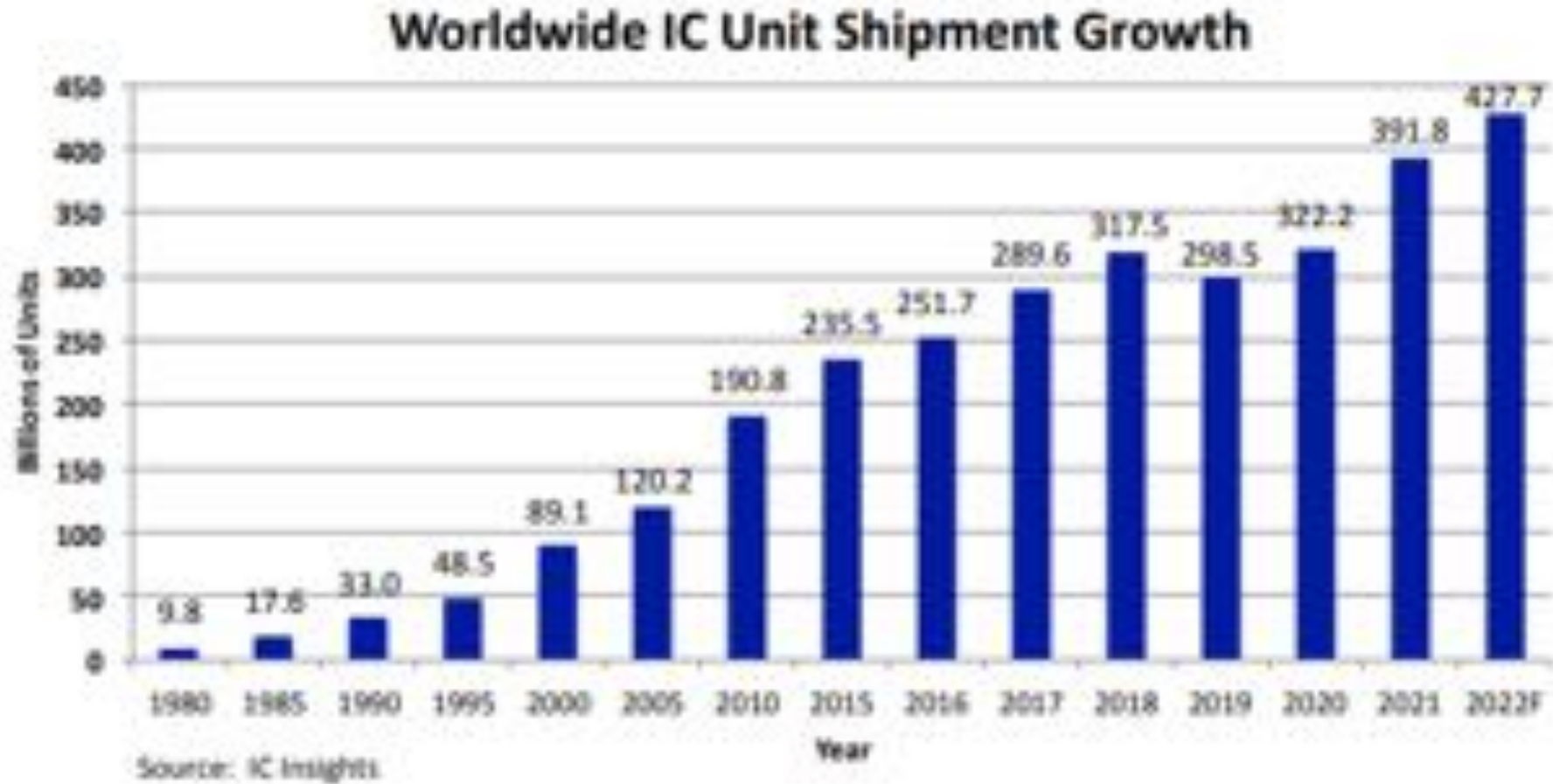
Understanding Global Wafer Capacity

2016-2022F IC Industry Capacity Trends (200mm Equivalents)

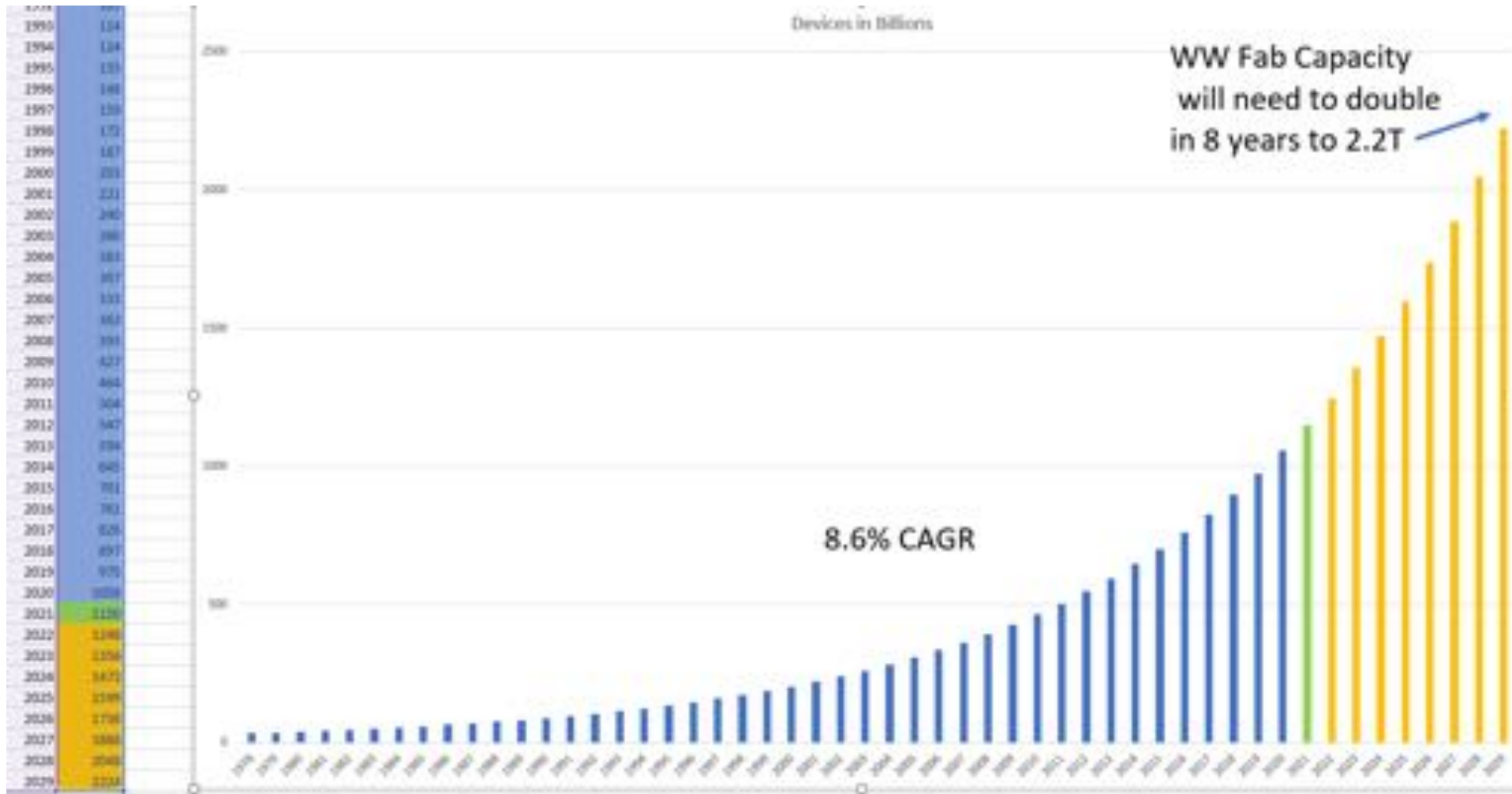
Year	Total IC Wafer Capacity (M)	IC Wafer Capacity % Chg	Total IC Wafer Starts (M)	IC Wafer Starts % Chg	Total IC Capacity Utilization
2016	178.9	4.0%	161.5	4.9%	90.3%
2017	190.5	6.5%	175.8	8.9%	92.3%
2018	201.6	5.8%	188.9	7.5%	93.7%
2019	209.8	4.1%	180.0	-4.7%	85.8%
2020	223.5	6.5%	191.1	6.2%	85.5%
2021	242.5	8.5%	227.5	19.0%	93.8%
2022F	263.6	8.7%	245.1	7.7%	93.0%

Source: IC Insights, Krometa Research, WSTS, SIA

2022 IC (minus Discrete Semiconductor)



Our Dilemma – Doubling Fab capacity in 8 years.



We will see more announcements like these



A rendering shows early plans for two new leading-edge Intel processor factories in Licking County, Ohio. Announced on Jan. 21, 2022, the \$20 billion project spans nearly 1,000 acres and is the largest single private-sector investment in Ohio history. Construction is expected to begin in late 2022, with production coming on line at the end of 2025. (Credit: Intel Corporation)

TSMC to Open advanced semiconductor fab in the United States

By **Electronics Media** · May 19, 2020



On May 15, TSMC announced its intention to build and operate an advanced semiconductor fab in the United States with the mutual understanding and commitment to support from the U.S. federal government and the State of Arizona.

This facility, which will be built in Arizona, will utilize TSMC's 5-nanometer technology for semiconductor wafer fabrication, have a 20,000 semiconductor wafer per month capacity, create over 1,600 high-tech professional jobs directly, and thousands of indirect jobs in the semiconductor ecosystem. Construction is planned to start in 2021 with production targeted to begin in 2024.

TSMC's total spending on this project, including capital expenditure, will be approximately US\$12 billion from 2021 to 2029. This U.S. facility not

Ad by **CRITEO**

Report this ad

Ad choices

We will see more announcements like these



by Rick Smith and Jason Parker, WRAL TechWire — January 5, 2022

RALEIGH – At least two major semiconductor manufacturers are considering a site south of the Triangle in Chatham County for the construction of a mammoth semiconductor manufacturing plant, an industry source tells WRAL TechWire. And a corporate real estate executive confirms that there is “lots of interest” in the location from multiple companies.

While not identifying the firms, a source in the semiconductor industry who requested anonymity said North Carolina is “well positioned” to land a project that could be worth as much as \$30 billion and create as many as 10,000 jobs.

We will see more announcements like these



by Rick Smith and Jason Parker, WRAL TechWire — January 5, 2022.

RALEIGH – At least two major semiconductor manufacturers are considering a site south of the Triangle in Chatham County for the construction of a mammoth semiconductor manufacturing plant, an industry source tells WRAL TechWire. And a corporate real estate executive confirms that there is “lots of interest” in the location from multiple companies.

While not identifying the firms, a source in the semiconductor industry who requested anonymity said North Carolina is “well positioned” to land a project that could be worth as much as \$30 billion and create as many as 10,000 jobs.

TSMC to Open advanced semiconductor fab in the United States

By Electronics Media · May 19, 2020



On May 15, TSMC announced its intention to build and operate an advanced semiconductor fab in the United States with the mutual understanding and commitment to support from the U.S. federal government and the State of Arizona.

This facility, which will be built in Arizona, will utilize TSMC’s 5-nanometer technology for semiconductor wafer fabrication, have a 20,000 semiconductor wafer per month capacity, create over 1,600 high-tech professional jobs directly, and thousands of indirect jobs in the semiconductor ecosystem. Construction is planned to start in 2021 with production targeted to begin in 2024.

TSMC’s total spending on this project, including capital expenditure, will be approximately US\$12 billion from 2021 to 2029. This U.S. facility not

Fab Expansion over the next few years

SemiMedia
A Forbive Group Member

Breaking News MarketWatch Distribution Manufacturer Video About us

Home > MarketWatch > 41 new fabs to be added globally from 2022 to 2025



41 new fabs to be added globally from 2022 to 2025

SemiMediaEdit
November 4, 2022 - MarketWatch

According to reports, after the semiconductor shortage, a wave of fab expansion will be set off from 2022 to 2025, and 41

Thank You!

How Long Does the Manufacturing Process Take?

- Determines Lead-time

