

Tech Briefing 2024

December 2024

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Hybrid Bonding Wafer-to-Wafer and Die-to-Wafer

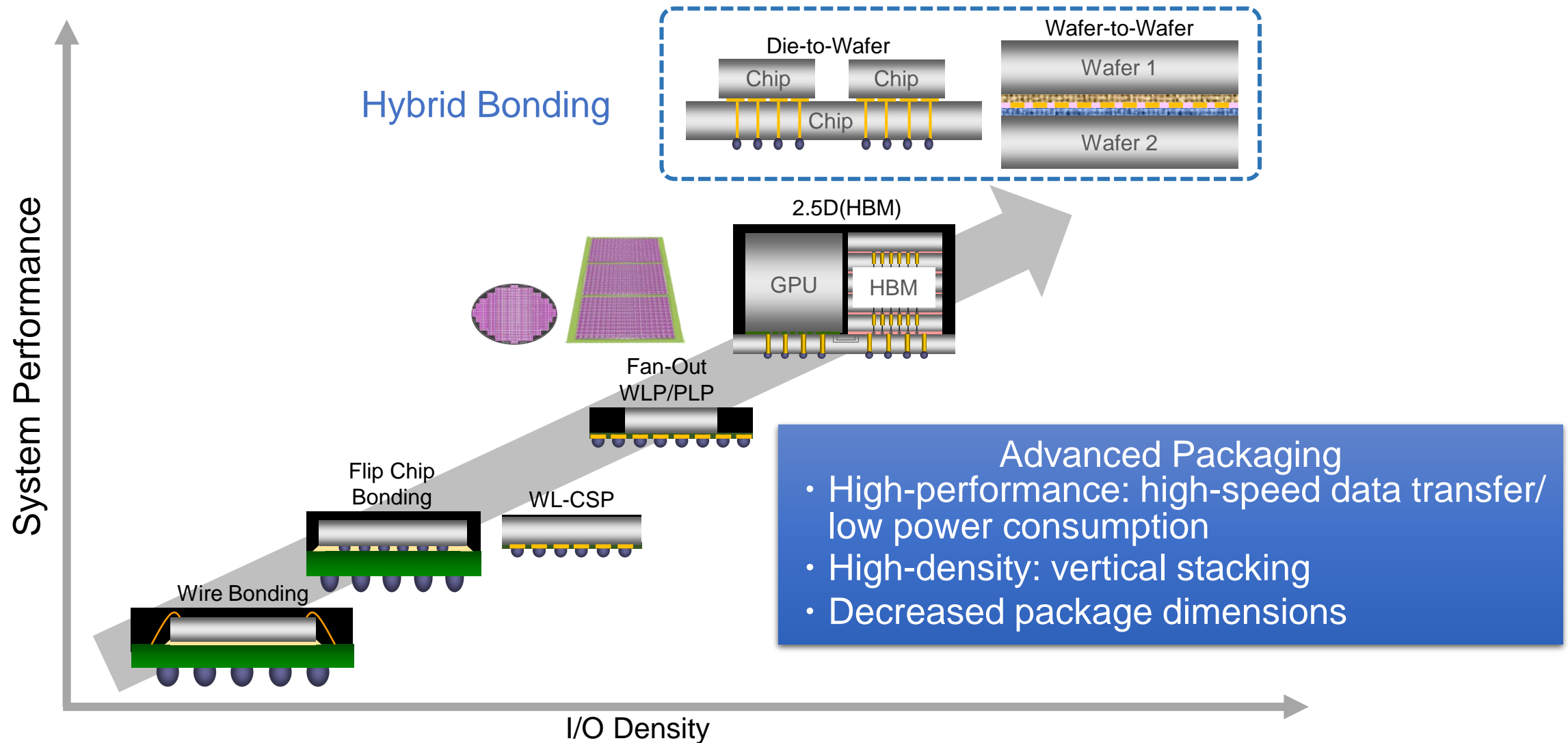
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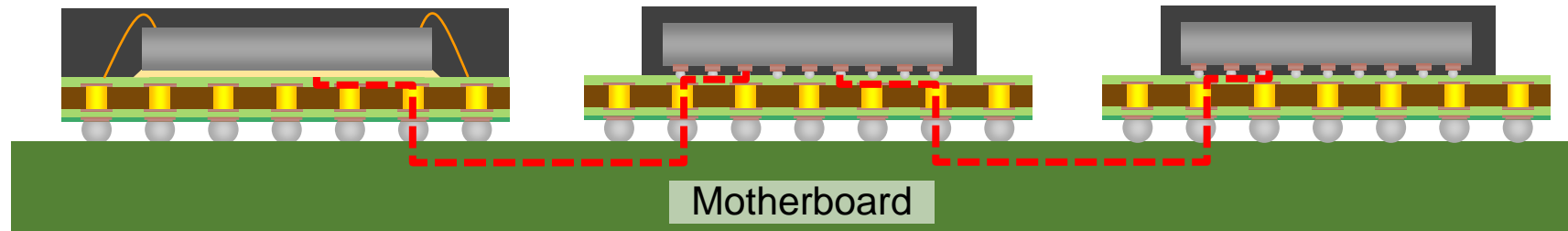
- What is Hybrid Bonding?
 - The Evolution of Packaging
 - Hybrid Bonding Features and the Hybrid Bonding Process
 - Wafer-to-Wafer (W2W)
 - Die-to-Wafer (D2W)
- KKM for Hybrid Bonding
 - W2W: Edge Trimming and Grinding
 - D2W: Dicing
- Summary

*The processes described in this document are not a complete overview of all the processes required with hybrid bonding.

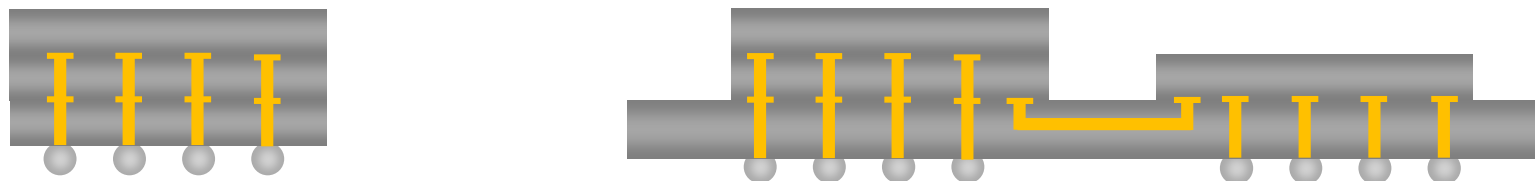
- Limitations on miniaturization in front-end processes have led to evolution of advanced packaging technology from a performance and cost perspective.



- Traditional packages
 - Long wire lengths used in wire, bump, and motherboard connections
→ increased transmission delay, power consumption, and die area



- Hybrid Bonding: technology to directly bond together different semiconductor die and/or wafers
 - Both metals and dielectric materials can be bonded. Enables short wire lengths and high density connections.



- 2 wafers and/or die are directly bonded together using a combination of metals and dielectric materials
 - Examples of common materials
 - Metal: Cu as used in wiring
 - Dielectric material: interlayer dielectrics such as SiO_2 and SiN

- Direct bonding process

- Surface processing and cleaning

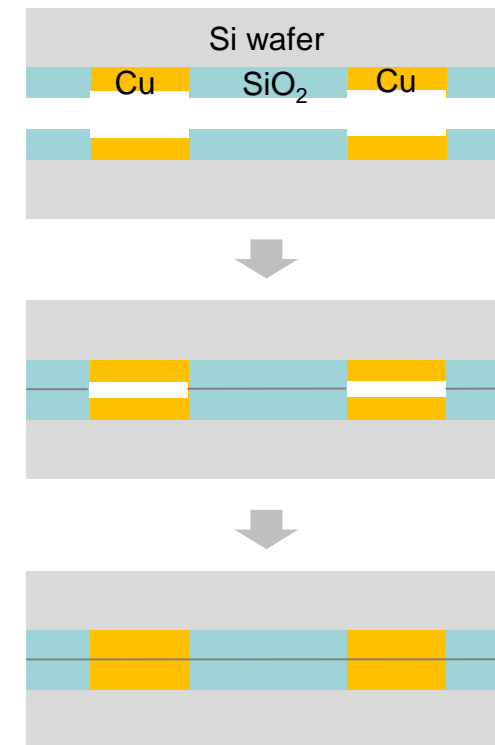
- Activation of wafer surface with plasma
 - Cleaning to remove particles

- Alignment

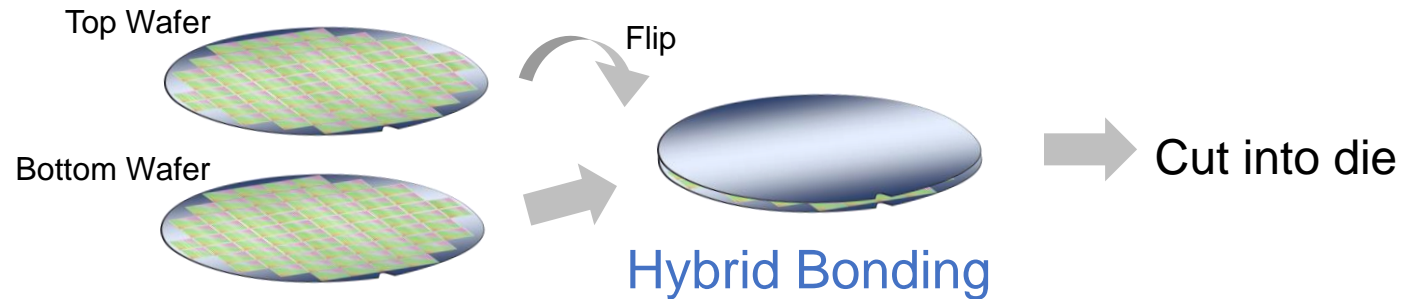
- Precise alignment to ensure metal components come into contact with a high level of accuracy

- Bonding and annealing

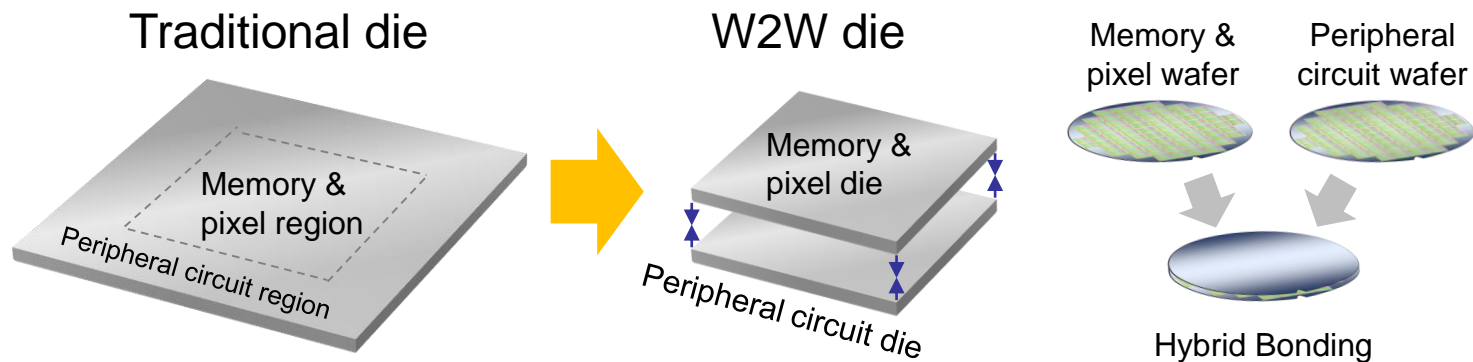
- Increased bond strength by performing heat treatment and crimping at room temperature



- Wafer to Wafer: wafer-level direct bonding
 - Features: High productivity with batch stacking
 - Risk of yield decrease
(defective die bonded and defects occurring in wafer-level processing)

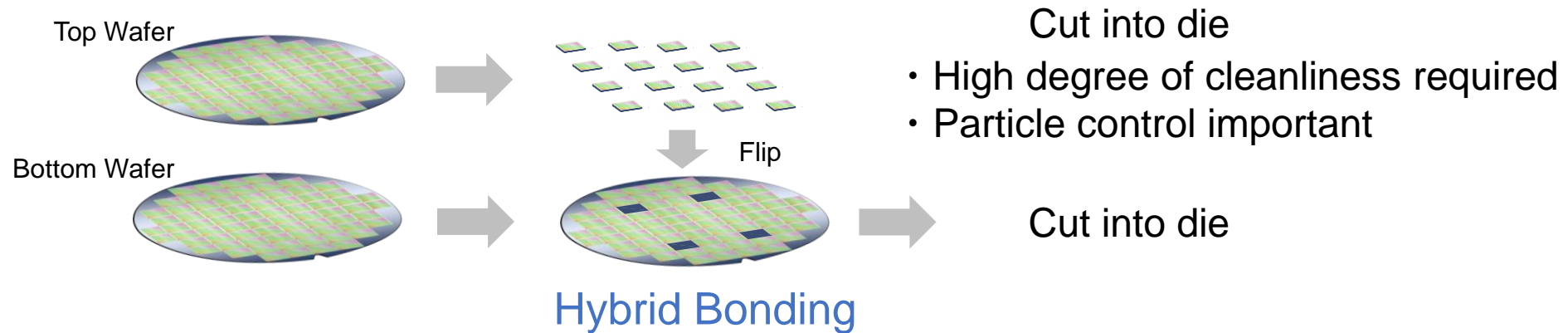


- Device applications: 3D NAND memory, CMOS image sensors, BSPDN, etc.
 - Usage example: creating a peripheral circuit on a separate wafer and then bonding it to another

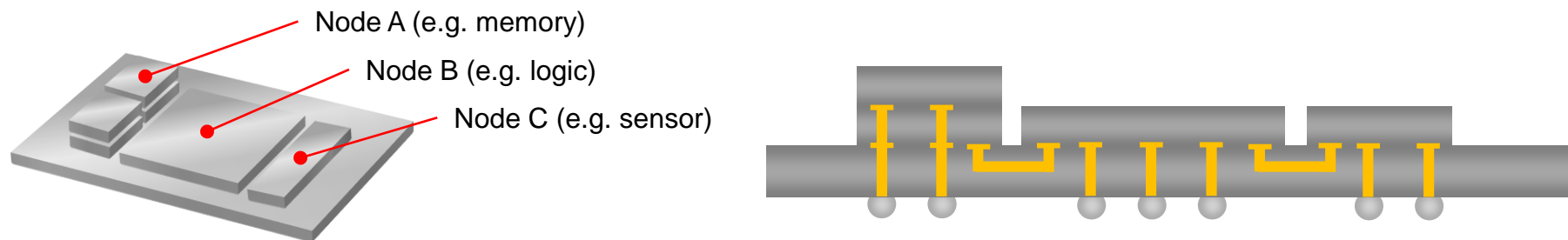


- Reduction of die area
- Wafer production using the optimal technology node

- Die to Wafer: After dicing, die are directly bonded onto wafers.
 - Features: Increased yield as only good quality die are bonded
 - Decreased productivity as each die must be bonded individually



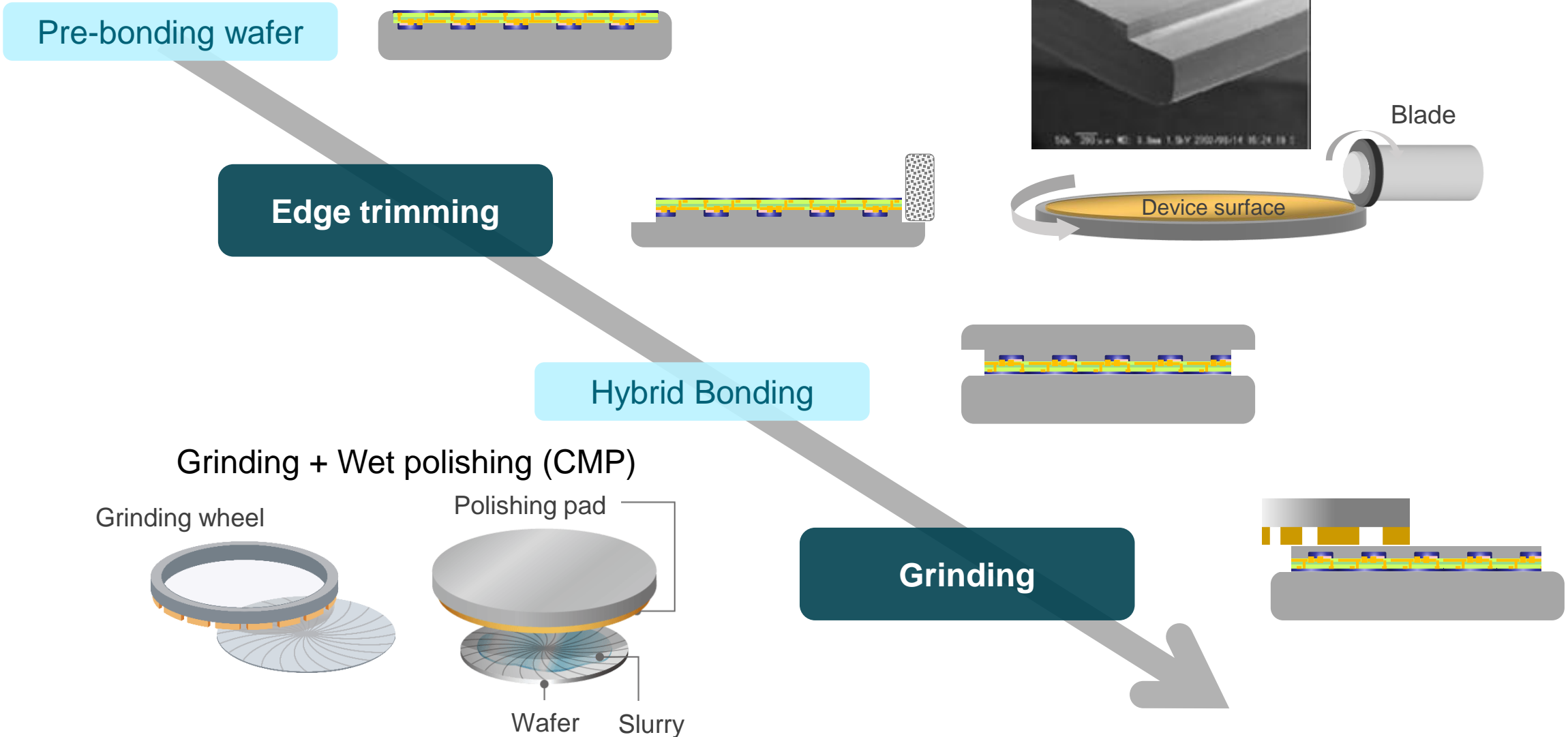
- Device applications: chipelets, etc.
 - Usage examples: Each component can be produced using the appropriate technology node and then die can be connected in the assembly process.



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- **KKM for Hybrid Bonding**
 - **W2W: Edge Trimming and Grinding**
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- Summary

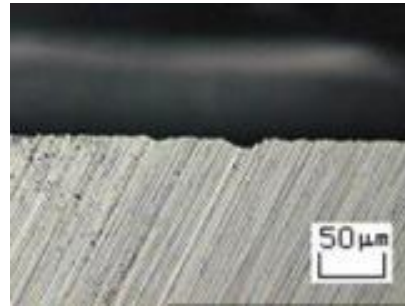
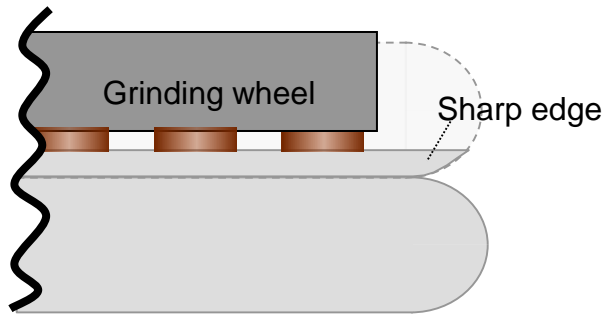
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- W2W process flow

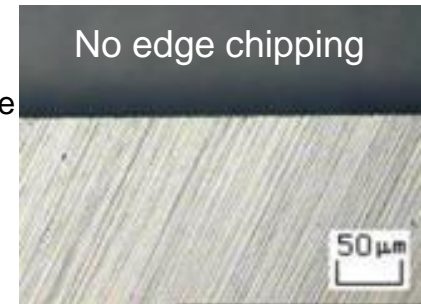
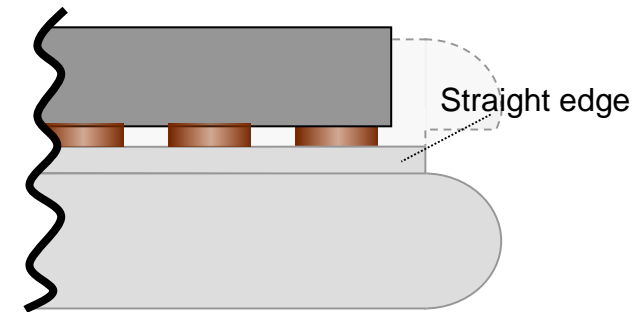


- Increased yield during thinning
 - Prevents edge chipping by removing sharp edges

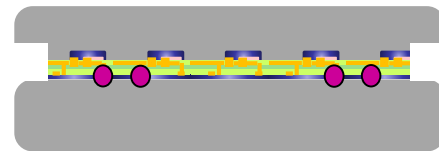
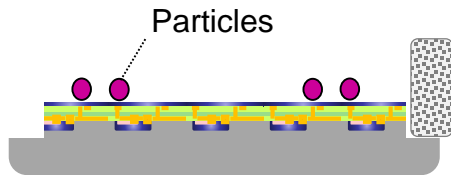
Without edge trimming



With edge trimming



- Issues with hybrid bonding
 - Risk of defective bonding if particles are present on wafer surface

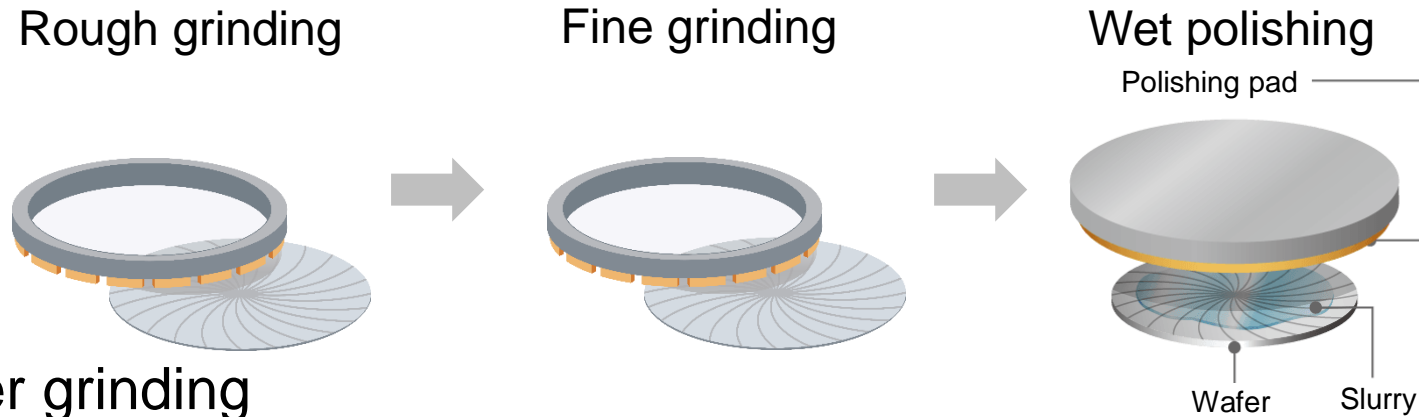


- Wafer cracking/peeling during grinding
- Results in defective die leading to decreased yield

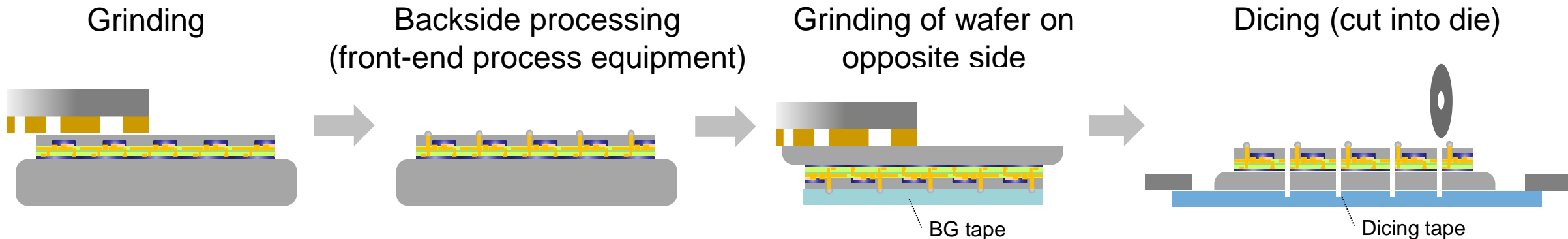


High degree of cleanliness required:
chemical cleaning possible after trimming

- With backside processing (using front-end process equipment) performed after grinding
 - high precision, highly clean grinding necessary
 - Grinding: achieve high precision processing through optimization of processing point layout
 - Polishing: achieve high degree of cleanliness with wet polishing (CMP) and chemical cleaning



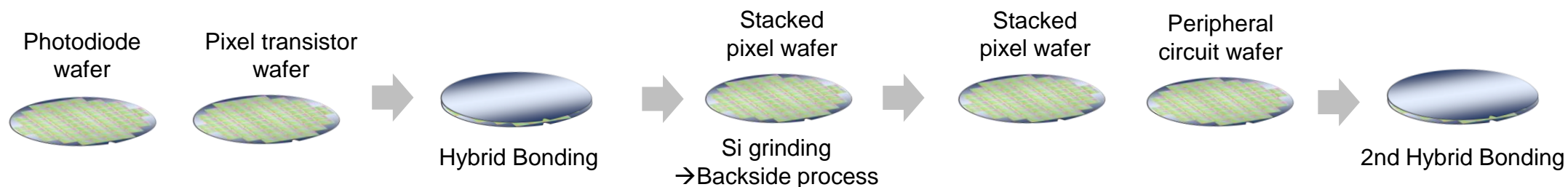
- Processing after grinding



- There may be further spread of KKM in the future if 3-layer stacking is adopted.
 → The number of times edge trimming and grinding is performed increases with each additional layer.

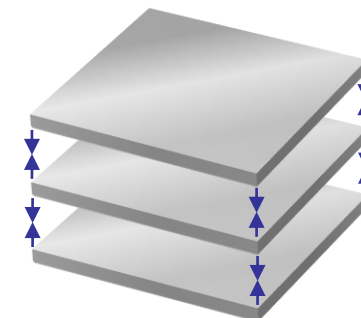
CMOS Image Sensor Example (1)

- Pixel wafers are divided into photodiode and pixel transistor wafers and stacked in 3 layers



CMOS Image Sensor Example (2)

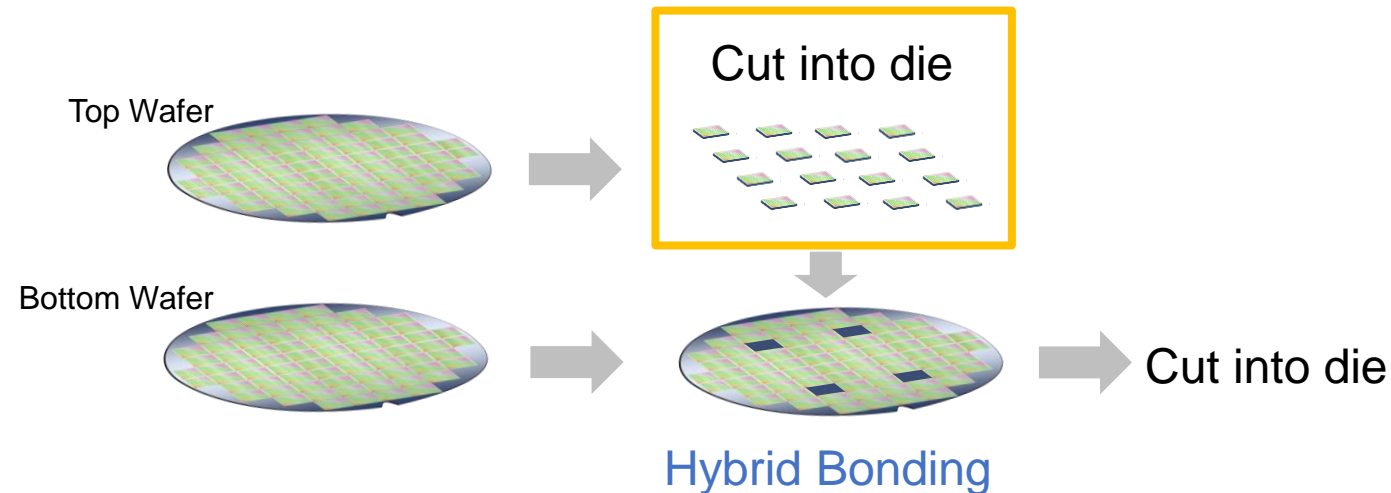
- A DRAM wafer, pixel wafer, and peripheral circuit wafer are stacked in 3 layers



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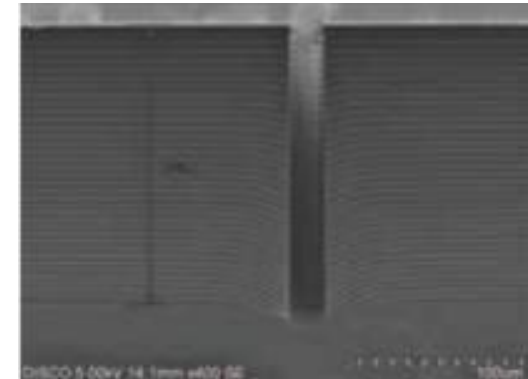
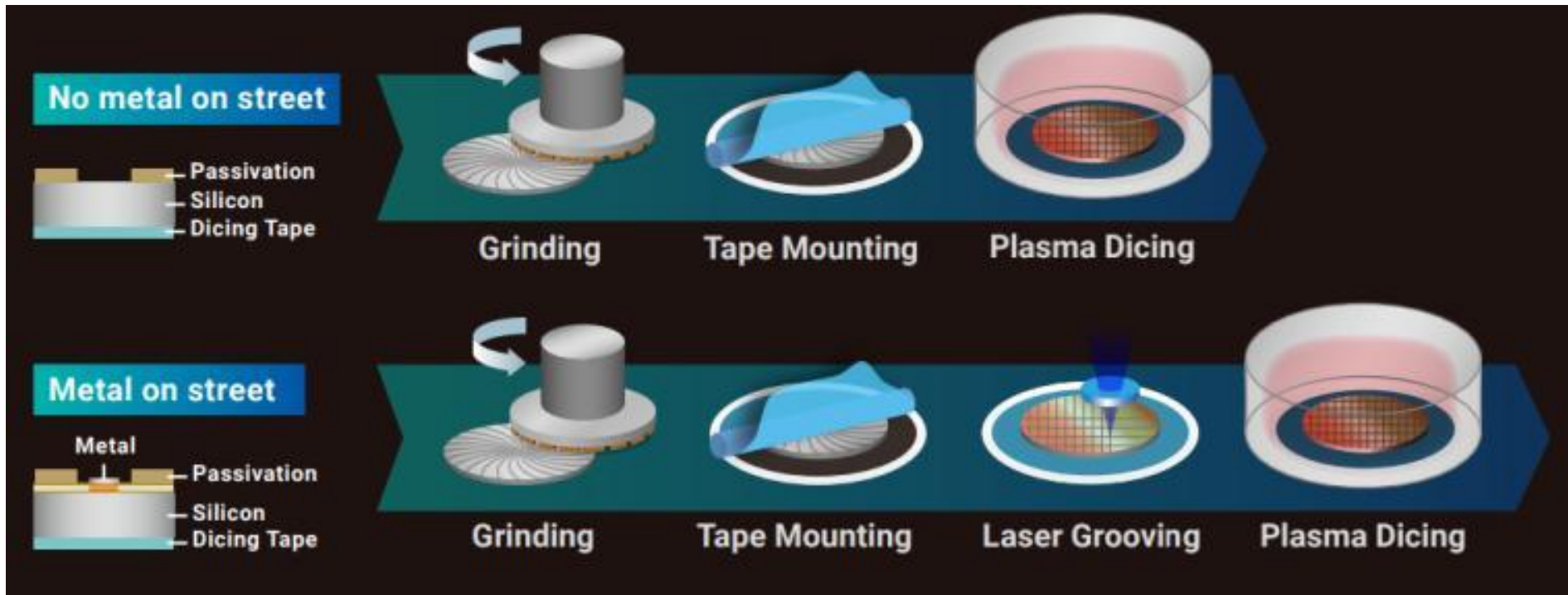
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- An important KKM process in D2W processing is dicing of bonded die.
 - A high degree of cleanliness is required in order to prevent bonding defects from particles.



- Dicing methods with a high degree of cleanliness
 - Plasma dicing
 - A processing method used to singulate die from wafers by performing dry etching under a vacuum
 - Blade dicing
 - Blade dicing which perfects the DBG process and the art of clean processing

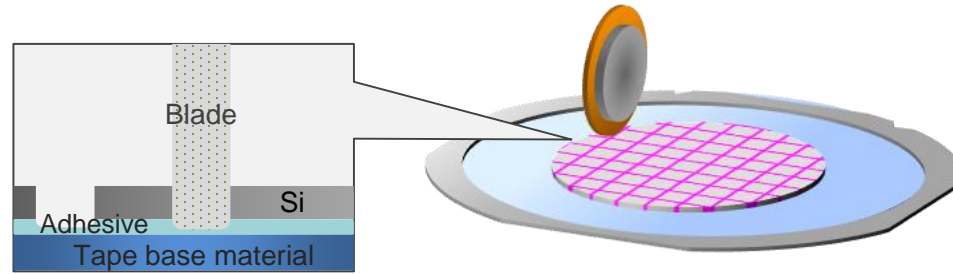
- Highly clean processing
 - As plasma dicing is a form of dry etching performed using a chemical reaction, there are no processing particles or melted debris.



- The Bosch Process using SF_6 and C_4F_8
 - Uses greenhouse gases with high global warming potential
 - High energy usage due to vacuum processing

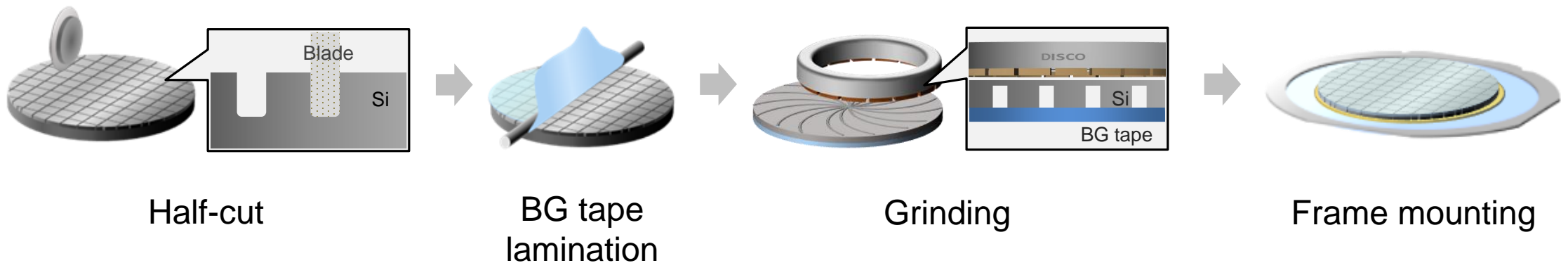
➔ Issue with CO_2 emissions

- A clean process which uses blade dicing
 - Normal dicing: Risk of particles adhering to die as cuts are made into the tape adhesive



- DBG (Dicing Before Grinding)

→ No particles arise from adhesive as processing does not involve cutting into the tape.



- Blade dicing which perfects the art of clean processing
 - Confirmed favorable bonding results which are equal to or better than those of plasma dicing
- Presentations given by imec, Yokohama National University, and other third party organizations.

Awards and Academic Presentations

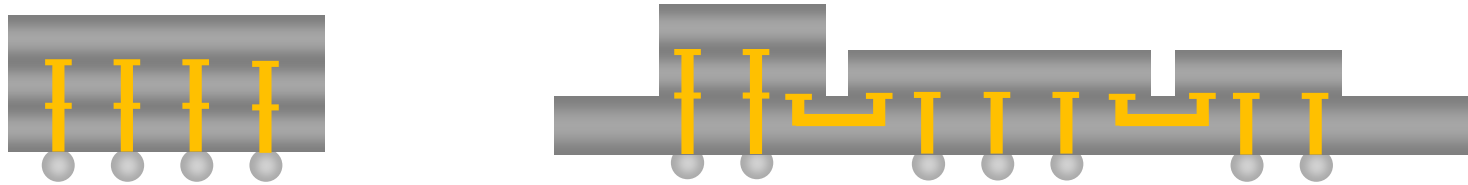
[1] IEEE 73rd Electronic Components and Technology Conference (ECTC2023)
“Inorganic Temporary Direct Bonding for Collective Die to Wafer Hybrid Bonding”
Fumihiko Inoue (Yokohama National University) et.al.,

[\[2\] IEEE International 3D Systems Integration Conference \(3DIC\)
Clean Dicing: An Alternative Blade Dicing Technique for Minimizing Particles in 3D Heterogeneous Integration
Akito Hiro \(imec\) et.al.,](#)

[3] Received Excellence Award in the Semiconductor Manufacturing Equipment Division of the 30th Annual Semiconductor of the Year Awards 2024

[\[4\] Awarded the Advanced Technology Award for Exemplifying Originality in the Member of Society Division of the 37th METI Minister Awards](#)

- The demand for hybrid bonding is increasing accompanying the evolution of packages
 - Hybrid Bonding: technology to directly bond together differing semiconductor die and/or wafers
 - Both metals and dielectric materials can be bonded.
Enables short wire lengths and high density connections.



- Hybrid bonding processes: Wafer-to-Wafer (W2W) and Die-to-Wafer (D2W)
 - W2W: direct bonding on a wafer level
 - Requires edge trimming along with high precision and highly clean grinding
 - D2W: direct bonding of die to wafers after dicing
 - Requires clean dicing of die which will be bonded

These Materials

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