Tech Briefing 2022

December 2022

Future of Wafer Singulation Technology

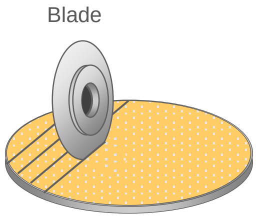
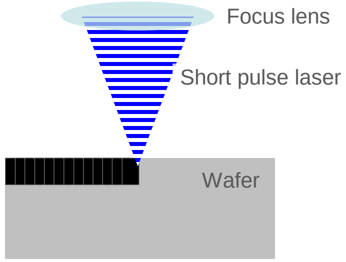
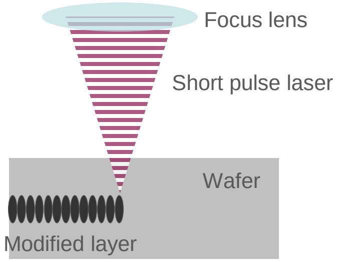
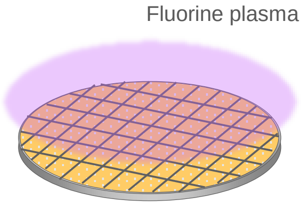
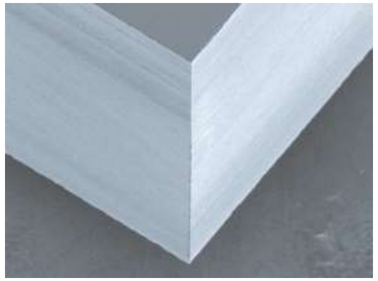
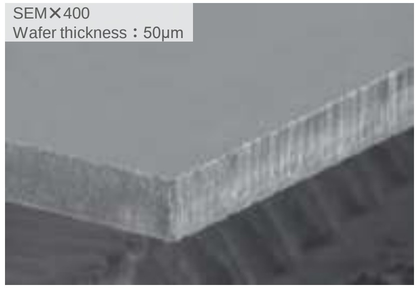
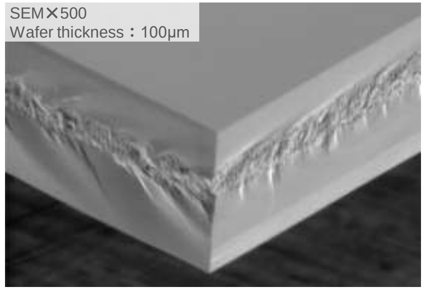
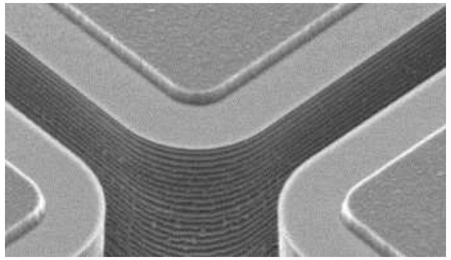
DISCLAIMER

Statements in this PowerPoint with respect to DISCO's current strategies, plans, estimates, and beliefs and other statements that are not historical facts are forward-looking statements about the future performance of DISCO. These statements are based on management's assumptions and beliefs in light of the information currently available to it and therefore you should not place undue reliance on them. DISCO cautions you that a number of important factors could cause actual results to differ materially from those discussed in the forward-looking statements, and you should not make decision on your investment thoroughly based on these statements. Such factors include, but not limited to, (i) general economic conditions and levels of demand in DISCO's markets; (ii) developments in technology and resulting changes in semiconductor and/or electronic component manufacturing process; (iii) levels of capital investment for manufacturing semiconductors and/or electronic components; (iv) expansions of the area for products and technologies using semiconductors and/or electronic components and its expanding speed; (v) DISCO's ability to continue to offer products and services corresponding to developments of new semiconductors and/or electronic components and new technologies for manufacturing them; (vi) exchange rates, particularly between the yen, the U.S. dollar, and the euro, and other currencies.

©DISCO CORPORATION All rights reserved

Major Singulation Technologies at DISCO

- Other than blade dicing technology, laser dicing and plasma dicing technologies are also part of our lineup.
- Here are the characteristics of each technology using Si dicing as an example.

	Blade	Laser Ablation	Laser Stealth Dicing	Plasma Dicing
Image				
Processing method	**Material is cut using a blade.**	**Laser is focused on the wafer surface and the material is sublimated and evaporated.**	**Laser is focused inside the workpiece to form a modified layer. Singulated using external force.**	**Material is removed using plasma etching gas.**
Cross-sectional view				
Characteristics	**・Highly versatile. Can handle various materials by changing the type of blade.** **・Industrially proved, established technology.**	**・Non-contact processing and mechanical load is low.** **・Can handle materials that are difficult to process with blade dicing.**	**・Processing particles are low because it is an internal process.** **・Dry processing without water.**	**・Entire wafer surface is processed all at once. For micro die.** **・Processing damage is low with high die strength.**
Use	**・Majority is IC/LSI**	**・To remove the insulating film with low mechanical strength (Low-k film) used in high-speed logic IC.**	**・MEMS devices with micro mechanical structure.** **・Image devices where particles are not allowed.**	**・RFID, etc.**

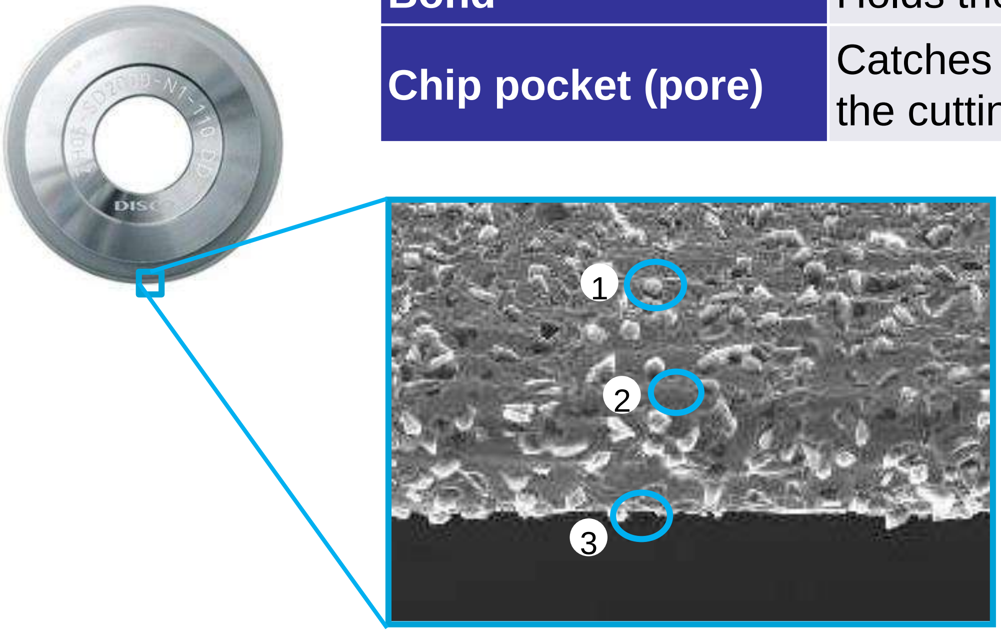
Blade Dicing Process

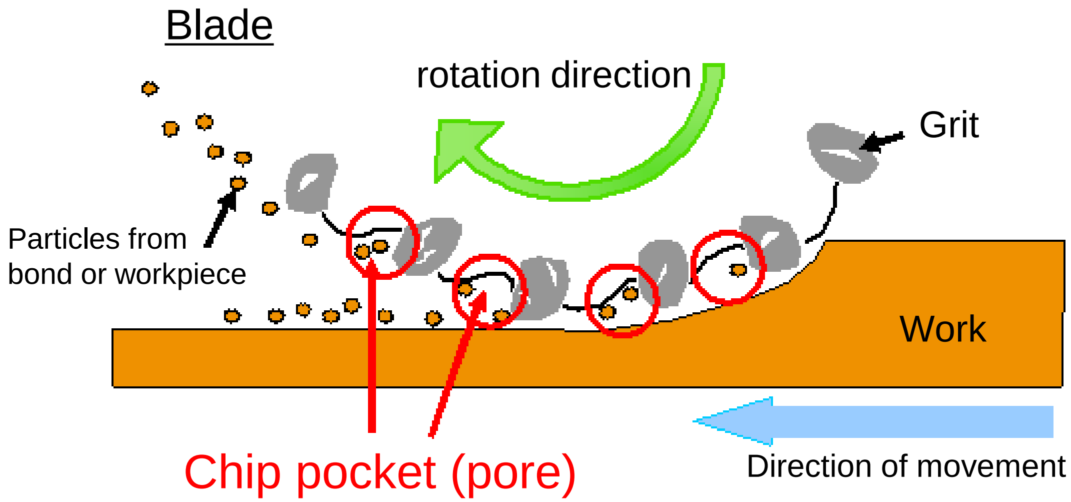
- Dicing process using the self-sharpening characteristics of a blade

The 3 major factors of a blade

Grit	Performs the actual processing
Bond	Holds the diamond grit together
Chip pocket (pore)	Catches the processing particles and the cutting water for a cooling effect

Dicing blade





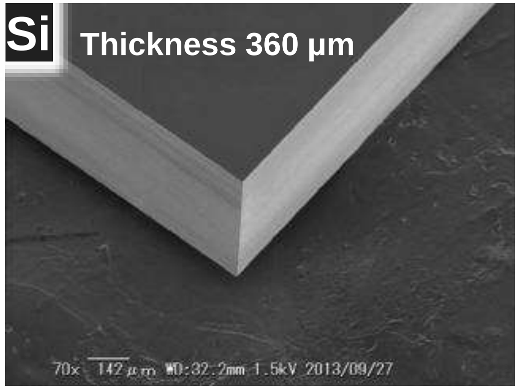
- **The chip pockets catch the particles generated during cutting.**
- **In addition, water also accumulates in the pockets, cooling the processing point.**

Examples of Applying Blade Dicing Equipment

- Used widely in cutting semiconductor IC, LSI, and various precision parts.
  - However, demands for processing technology are becoming advanced due to structural evolution and material change.

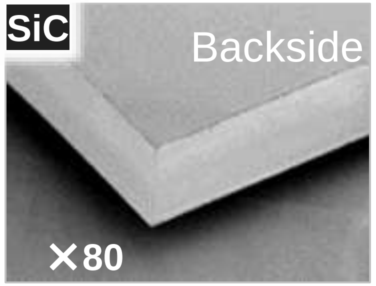
Change in shape and structure

Category	Device	Tendency of changes	Current
Semiconductors	DRAM	Lower profile substrate (thinner)	Si thickness: 50-150 µm
	NAND	Increase in layers for cell transistors Lower profile substrate (thinner)	Si thickness: < 50 µm
	Logic	Circuit miniaturization, high integration Lower profile substrate (thinner)	Si thickness: < 50 µm
	RFID	Miniaturization of die size	Die size < 1 mm
Electrical components	Ceramic capacitor	Multi-layer for internal circuit Miniaturization of die size	Capacitor size 0.2 x 0.4 mm
Medical devices	Ultrasonic probe (PZT)	Higher frequency	Frequency 2 – 12 MHz



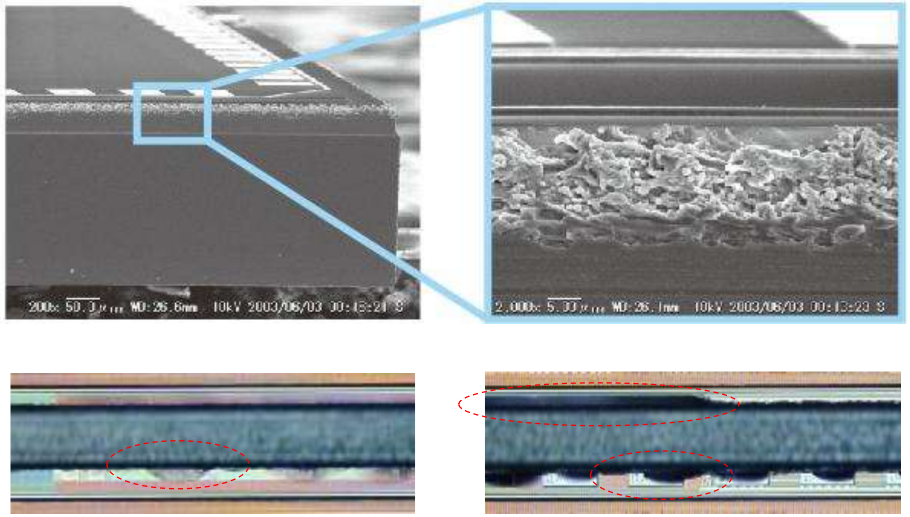
Change in material (conventionally Si wafer)

Category	Device	Tendency of changes	Increasingly used materials
Semiconductor	Power device	Energy saving Miniaturization	SiC GaN
Electrical components	SAW filter	Higher frequency	LiTO3 LiNbO3

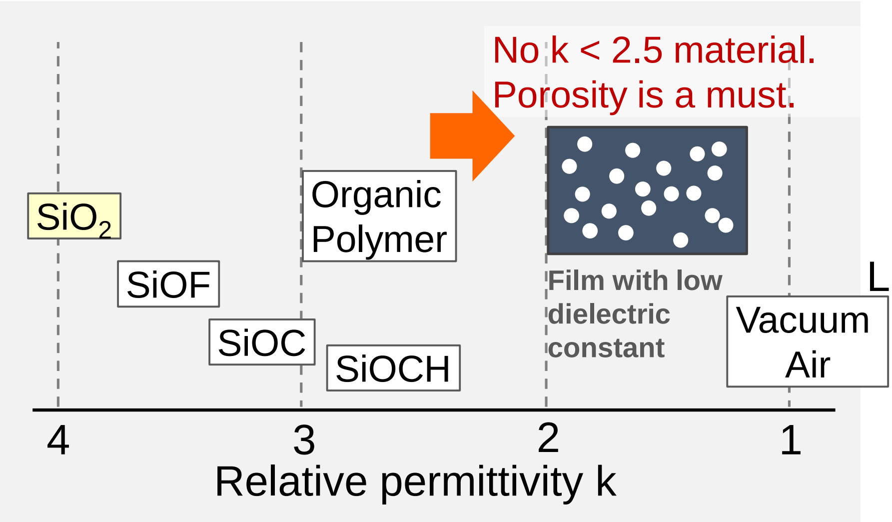


Challenges of Low-k Processing

- LSI miniaturization and multi-layer wiring
- Low dielectric material (low-k) adopted for interlayer dielectrics (ILD)
- Layer peeling occurs as mechanical strength of the layer is weak

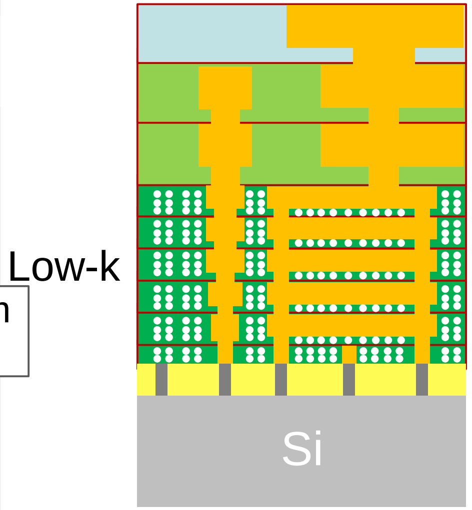


In order to reduce the permittivity, nano-level cavities are created on the entire film. Mechanical strength declines.



No k < 2.5 material. Porosity is a must.

Cross-sectional view of wiring layer

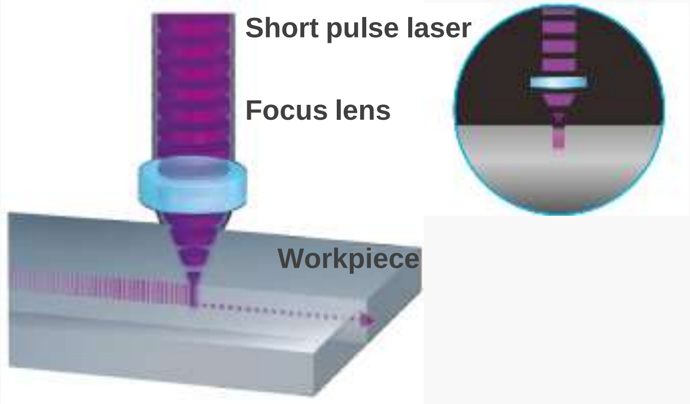
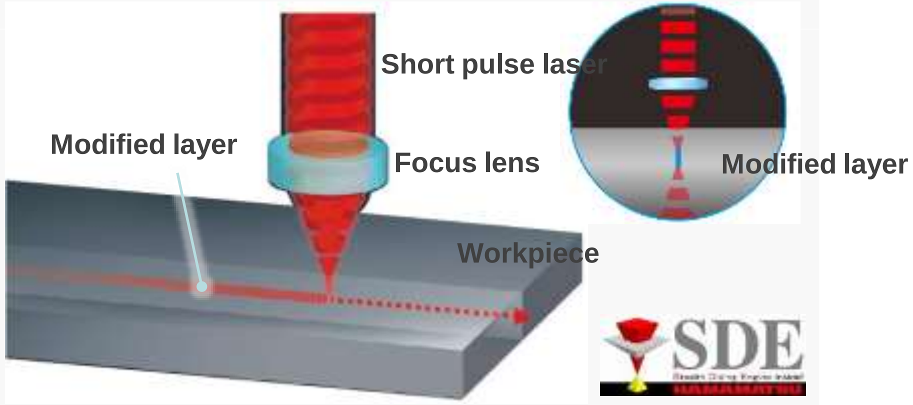


Low-k layer in the middle moves downwards due to mechanical processing

Processing with low mechanical load is required

Laser Processing Method Provided by DISCO

- Two main processing methods are provided

Process	Laser ablation	Stealth dicing
Processing method	Laser is focused on the surface  	Laser is focused inside the material 
Advantage	Can be applied to a wide range of applications	Narrow kerf Dry process
Disadvantage	Debris	Workpieces that can be processed by SD are limited (E.g.: Material, die size, with or without metal layer film)
Major device	Logic Controller BSI (image sensor) LCD driver	MEMS NAND flash memory Line sensor

Laser Ablation Processing Principle

- Laser is absorbed by the target material and vaporized at the surface
- Laser head with a good laser absorption with regard to the workpiece is required

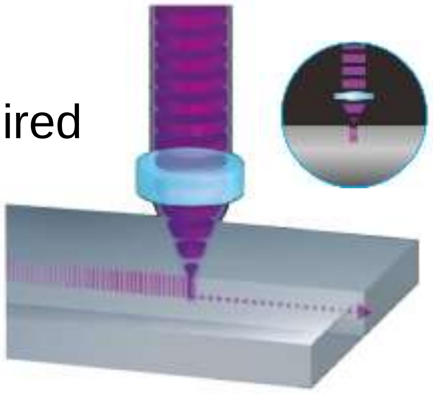
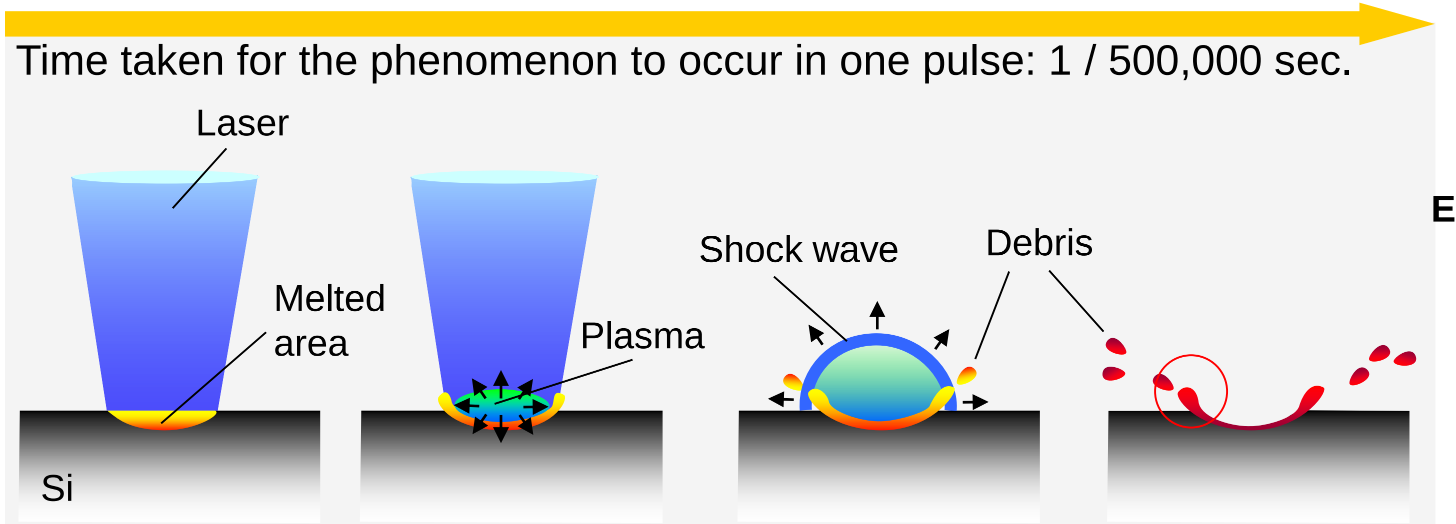


Image of Processing Phenomenon



Time taken for the phenomenon to occur in one pulse: 1 / 500,000 sec.

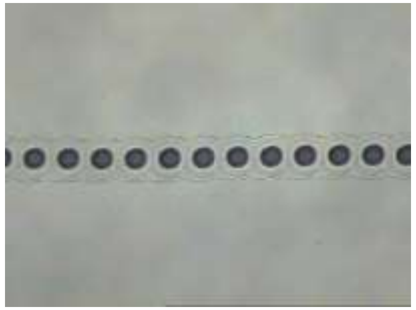
Si surface is melted using laser irradiation

Plasma formation and expansion creates a pressure in the surrounding area

A shock wave occurs and the melted particles (debris) scatter

Melted area on the surface continues to scatter

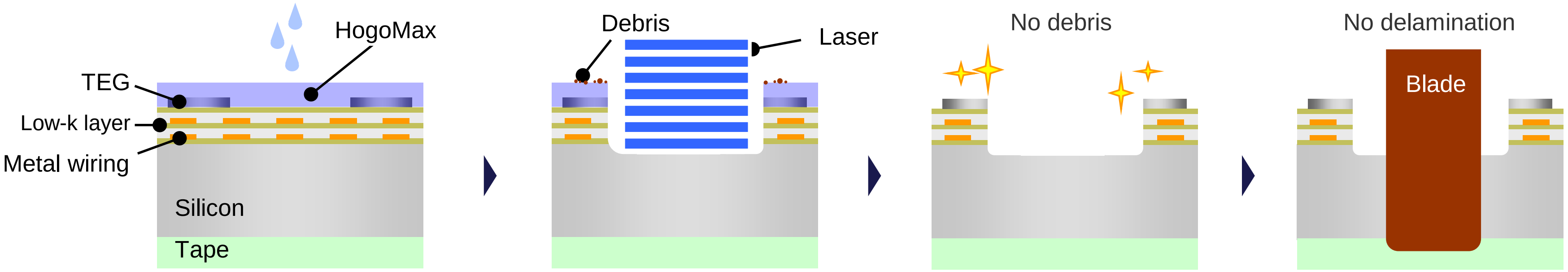
Example of Si processing: A case where the pulses do not overlap



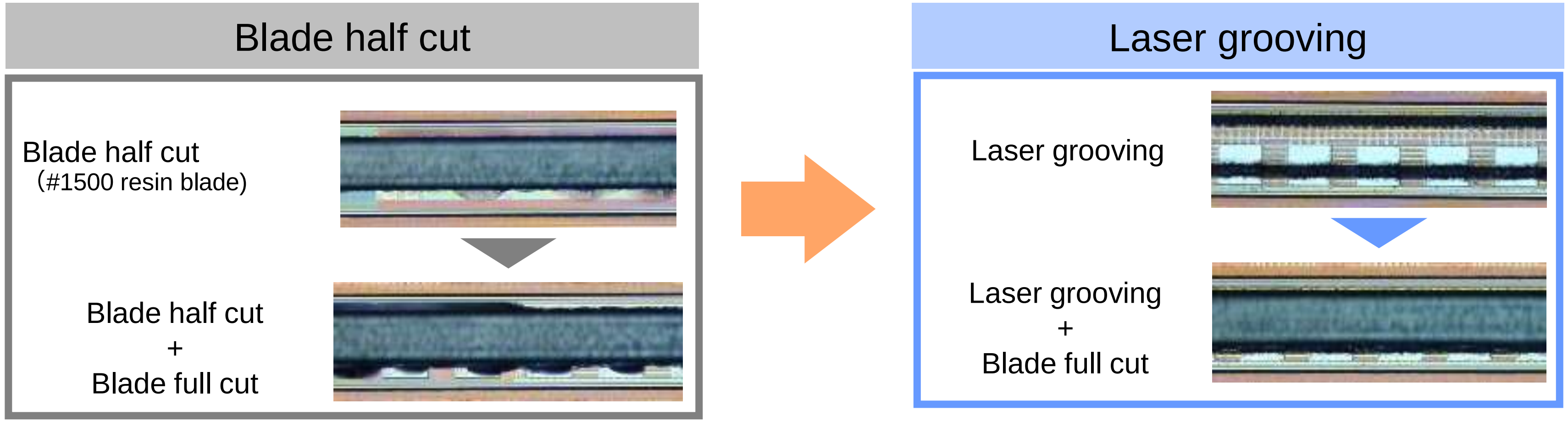
Energy is focused on the wafer surface → Possible to handle various materials

Combined with Blade Dicing

- Wiring layer is removed using a laser that does not directly come into contact
- No interlayer dielectrics (ILD) peeling as no mechanical processing load is added from processing



Protective film coating **Laser grooving** **Spinner cleaning** **Blade dicing**



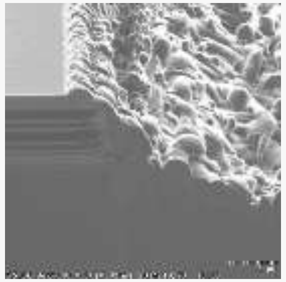
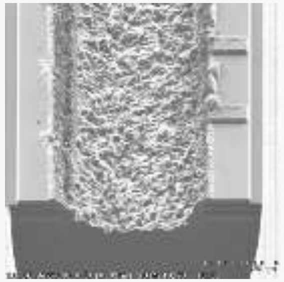
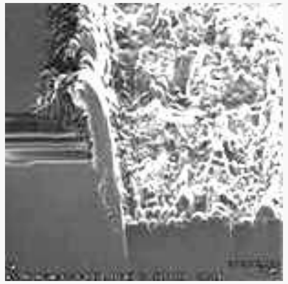
Film peeling from blade dicing

No film peeling, no debris

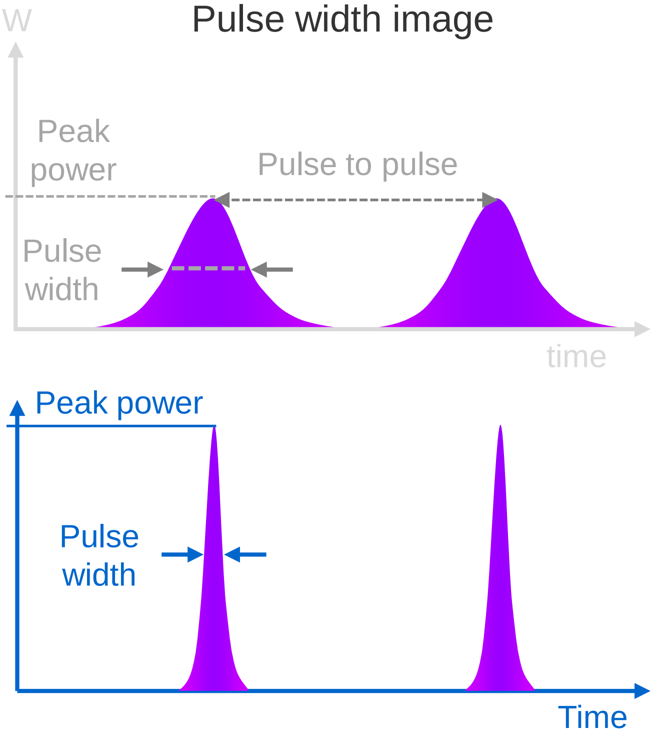
The Direction That Laser Development is Proceeding in

- Laser processing with minimal heat damage
  - Compared to the conventional laser, the duration of one pulse is shorter and melting during processing is minimal.
  - Optics design is critical as laser head is outsourced.

Application example: Si laser grooving

Pulse width	Cross section
Current laser	 
Short pulse laser (under dev.)	 

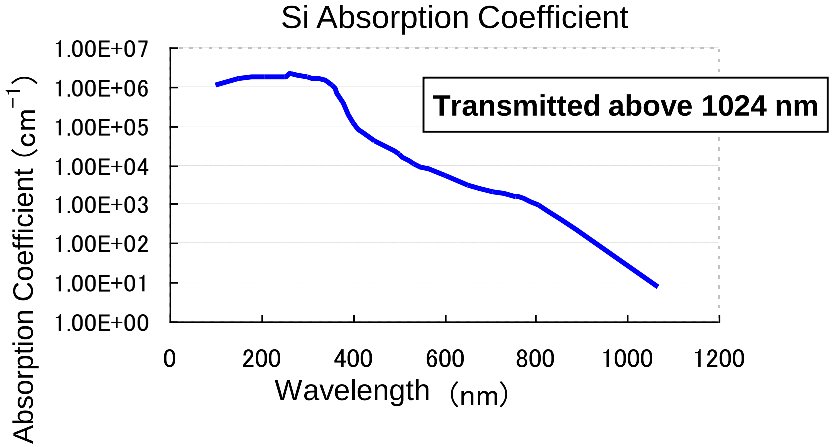
Pulse width image



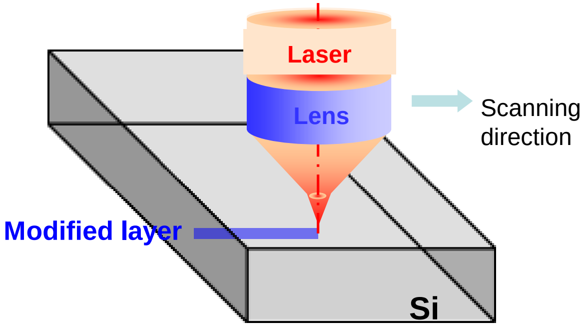
Advantage	Disadvantage
Heat load is minimal	Difficult to groove deeper Optical parts deterioration

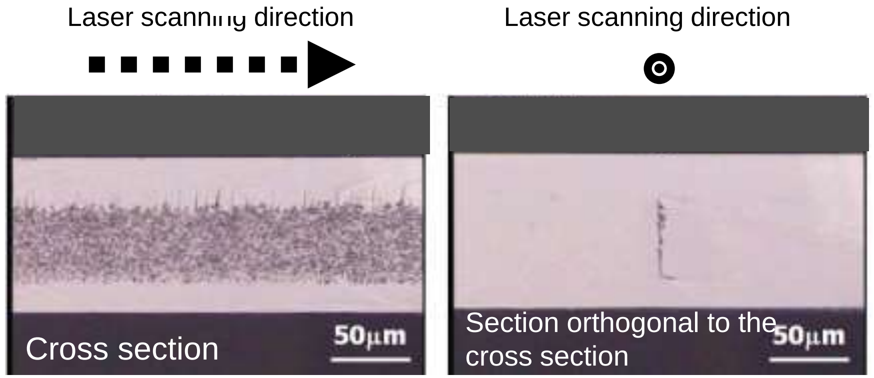
Stealth Dicing Processing Principle

- SD Process Flow
  - Modified layer formation
    - By focusing a laser beam that can be transmitted through Si, nonlinear absorption occurs.
      - No damage other than at the focus point



  - Modified layer formation

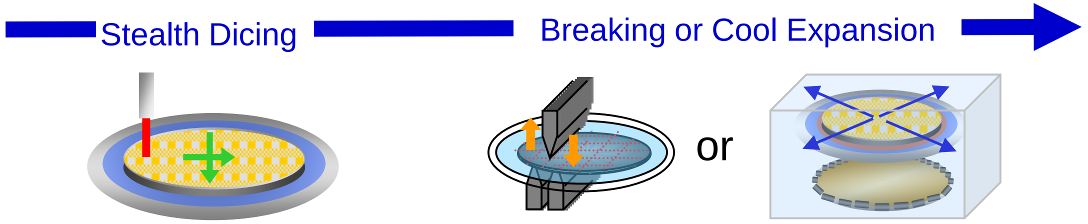




Cross section

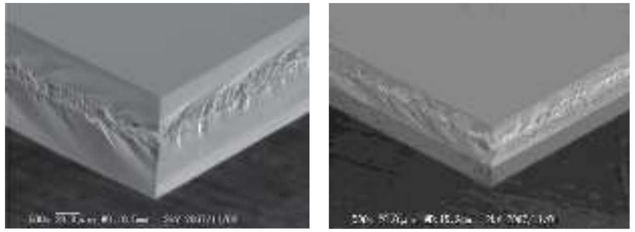
Section orthogonal to the cross section

Mounted on expandable tape



Characteristics of Stealth Dicing

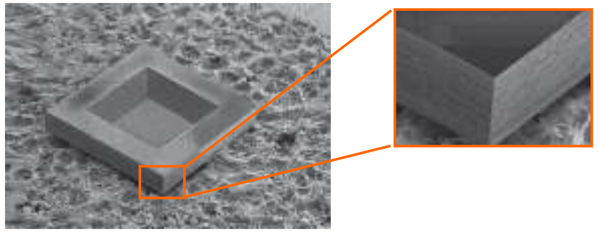
- Dry process without using water
  - Possible to process MEMS wafers, where water is not allowed, without any damage
- No mechanical load on the workpiece during processing
  - Possible to process thin wafer/MEMS with low strength



Silicon device

Wafer with
narrow street

Thin wafer
with DAF



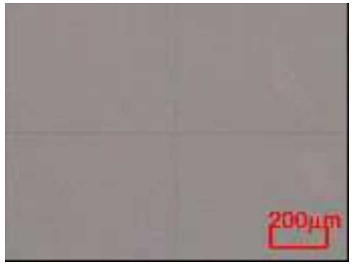
MEMS

MEMS where water is not allowed

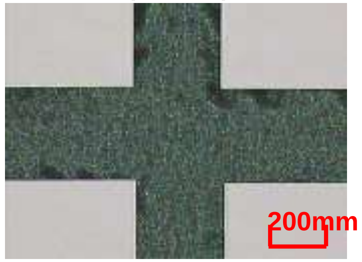
- No contamination generation
  - No processing particles are generated as modification occurs inside the workpiece
- Almost no kerf width
  - As kerf width can be made extremely narrow, the die obtained per wafer increases

Compared to a dicing saw, 10 times the water of a 25 m pool can be saved

After SD

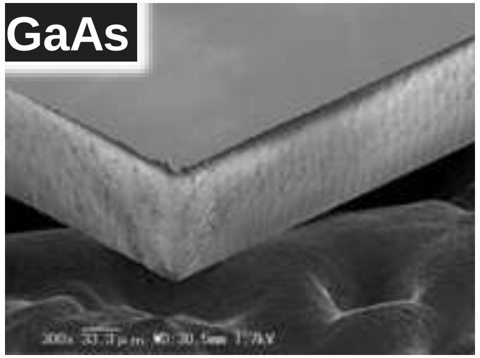


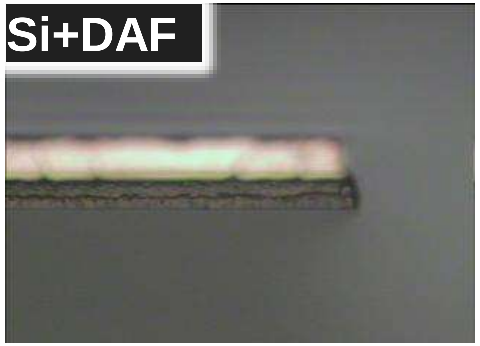
After tape expansion



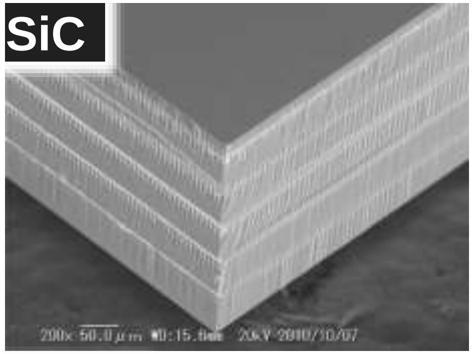
Laser Processing Examples

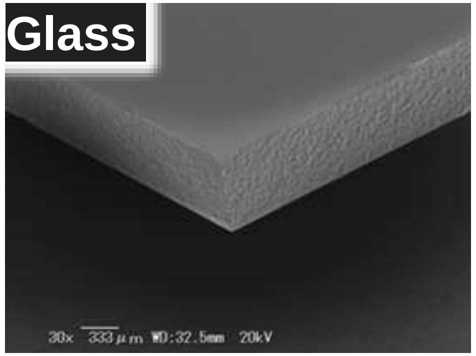
- Ablation
  - Devices that use an insulating film (low-k) between circuits
    - Logic
    - Controller
    - BSI
    - LCD driver
  - Analog device
    - RFIC
  - Power device
    - IGBT
  - Others
    - DAF cut


GaAs


Si+DAF

- SD
  - Water is not allowed
    - MEMS (Si microphone)
  - Ultra-thin device
    - NAND flash
  - Long or small die
    - Line sensor
  - Viscous material
    - SAW device
  - Illumination
    - Blue LED
  - Others
    - Multi-layer DRAM
    - Si-photonics


SiC


Glass

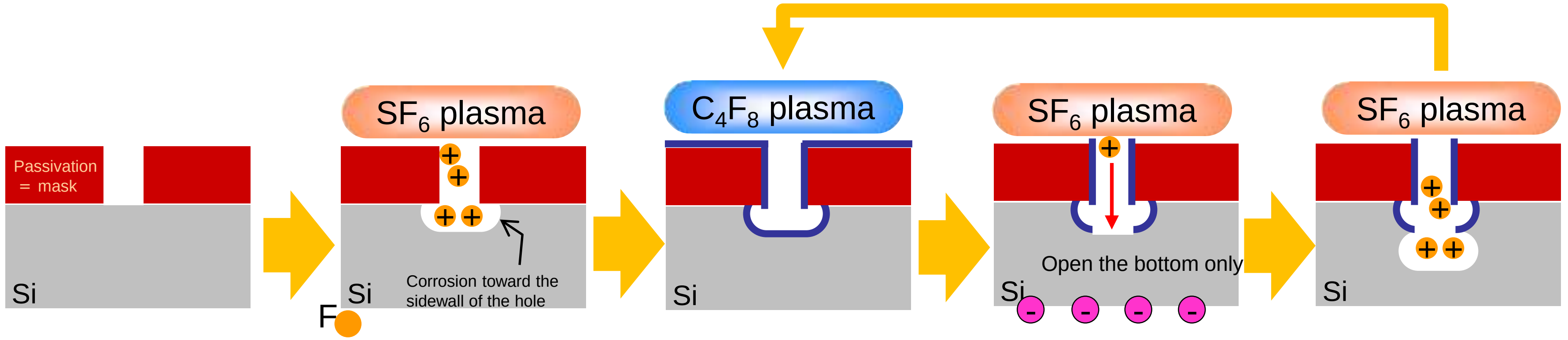
Adopted in many areas due to the superiority of laser processing
→ Mostly to complement blade dicing or for areas that cannot be handled by blade dicing

➡ No mechanical load, but this does not mean that there is no damage

Plasma Dicing Processing Principle

- Basic principle is dry etching using reactive gas
  - When making thin and deep holes using standard etching, corrosion occurs toward the sidewalls (Fig.2)
  - For this reason, the Bosch Process is used (process developed by the German company Robert Bosch in 1992)
  - By repeating the “etching” and “deposition” processes alternatively, it is possible to dig a deeper hole

Bosch Process:



1. Masking

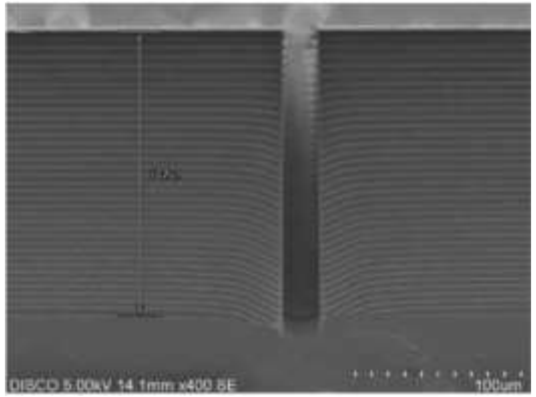
2. Isotropic etching

3. Protective film creation

4. Anisotropic etching

5. Isotropic etching

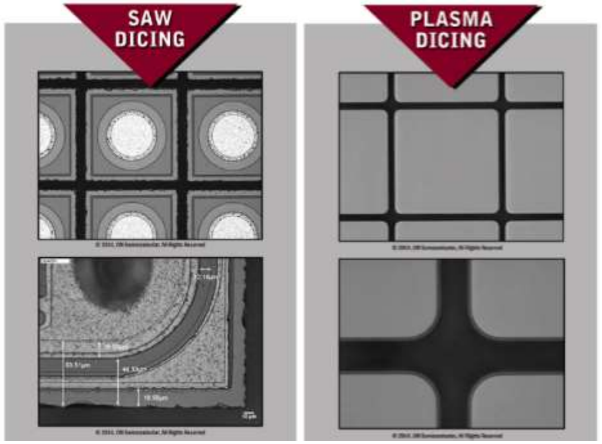
Processing example



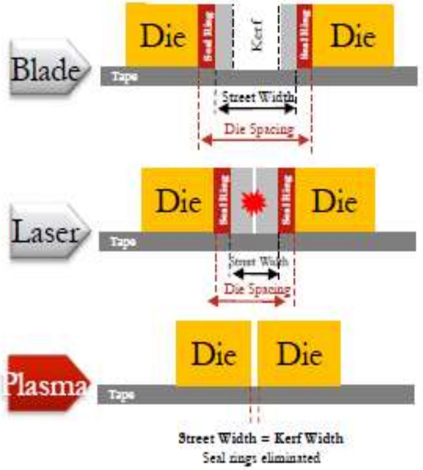
Characteristics of Plasma Dicing

- Die strength improvement
  - Possible to achieve no cracks or chipping
  - No physical or thermal damage

- High UPH
  - Surface processing allows separation of all lines at the same time



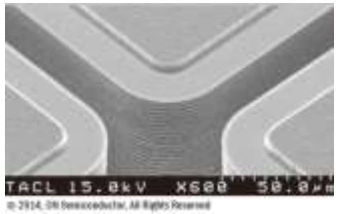
Die strength



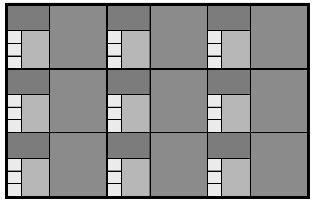
Seal ring

- No. of die per wafer can be increased by making the street width narrower
  - Narrow kerf due to dry etching
  - Seal ring is not required as there is no chipping
  - No cut shift

- Can process irregular shapes
  - Round corners
  - Hexagonal shapes
  - MPW, round shapes, etc.

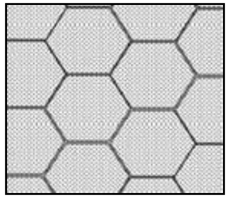


Round corner



MPW

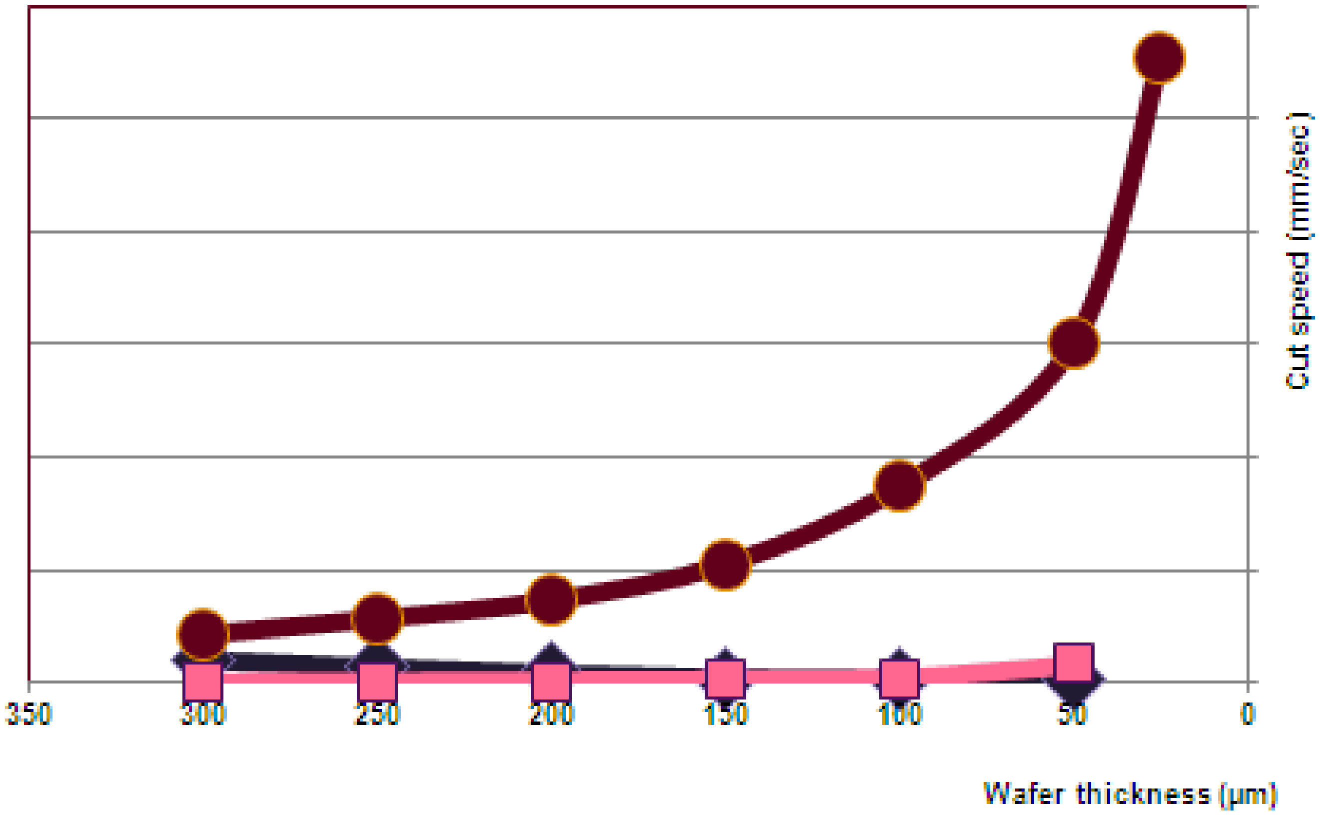
Round



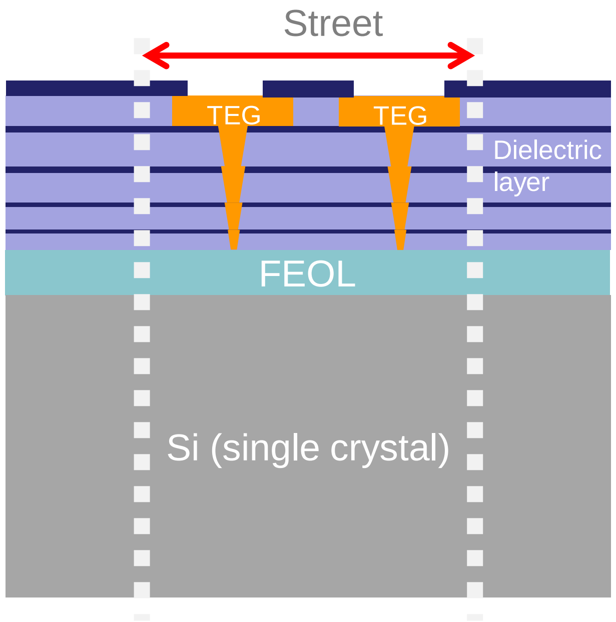
Hexagon

UPH Compared to Other Processes

- UPH drastically increases as the wafer becomes thinner
  - Plasma dicing is not suitable for thick devices



Structure of Dicing Area (Street)



Street (dicing area):

Circuit layer: SiN, SiO2, interlayer dielectrics (ILD), circuit metal

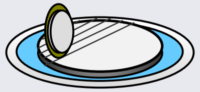
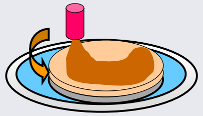
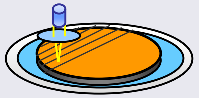
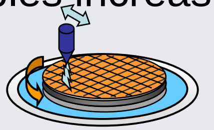
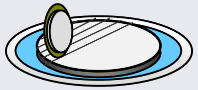
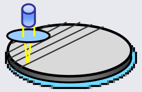
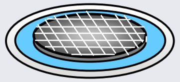
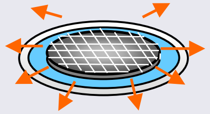
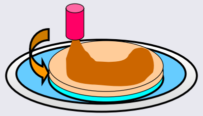
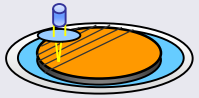
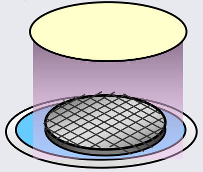
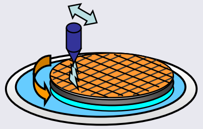
FEOL layer: p-type Si, n-type Si, oxide film, contact metal

Si substrate: single crystal (physical property changes based on dopant amount)

Blade	Various materials can be processed. As long as blade loading does not occur, processing is possible. It is not suitable for mechanically delicate materials.
Laser	Laser wavelength and material used (absorption rate) need to be matched. Material is not sublimated but melted instead, so processing quality deteriorates.
Plasma	If the material is suitable for plasma, high processing quality can be achieved, but there is no versatile etching gas. It tends to be high cost because of mask processing and exhaust gas processing.

Comparison of Processes

- Process flow comparison (singulation after thinning)

Blade dicing	Simple with not many processes  Blade dicing
Laser ablation	No. of processes and consumables increases  HogoMax coating  Laser grooving  HogoMax removal  Blade dicing
Stealth dicing	Materials that can be processed are limited  Stealth Dicing  Tape remount  Tape expansion
Plasma dicing	No. of processes and consumables increases. Gas processing facility is required. Suitable materials are limited.  Resist coating  Laser grooving  Remote plasma  Resist removal

Cost Comparison (Image)

- There are advantages and disadvantages for each application.
- Plasma dicing is a good method if the device is suitable for plasma dicing.
  - For needs that place emphasis on safety such as automotive devices
  - For thin φ300-mm Si with small die: High added value

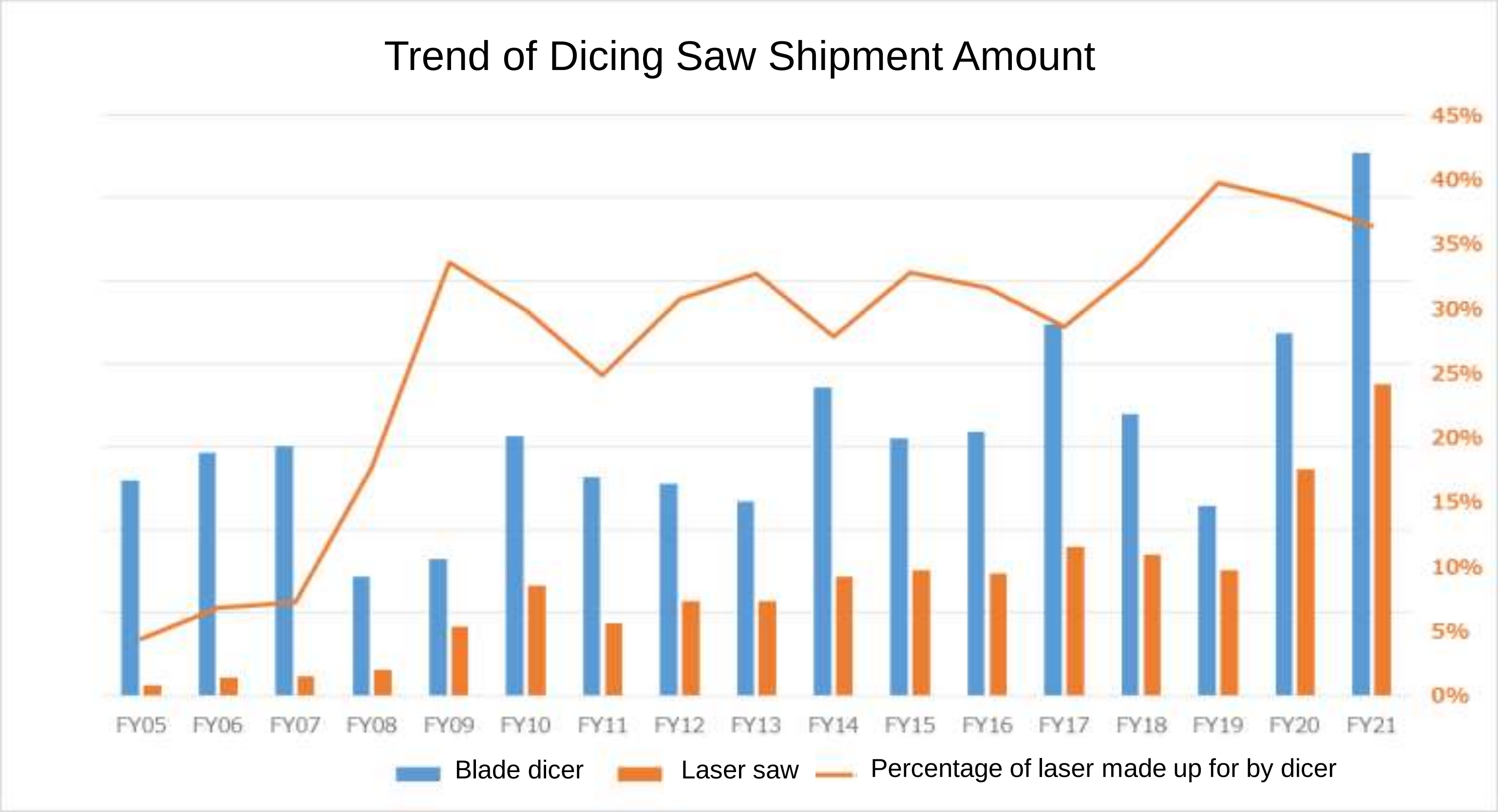
Image:

	Blade dicing	Laser ablation	Stealth dicing	Plasma dicing
Equipment price (fully automatic)	1	3 to 5 or more	4 to 7 or more	6 to 10 or more
Consumables/year	1	1 to 5 or more	1	2 to 6 or more
Water, air, electricity	1	0.1 or less	0.1 or less	5 ?
# of wafers processed/h	1	1 to 5 (depends on material)	5 or more (depends on material)	10? (if suitable)
Thickness that can be full cut	70 to 775 μm	150 μm or less	50 to 775 μm	775 μm (lower UPH as wafer thickness increases)
Unsuitable materials	Metal, viscous materials (GaAs, SiC, LT), multi-layer structure	Thick materials (if too much heat is applied, molten substances may be generated)	Metal, ceramic, materials with film, materials that do not allow inner laser focusing	Materials other than Si

*May differ from the above depending on various conditions

Sales Transition of Laser Equipment

- First equipment was released in 2002
  - Laser equipment did not compete with blade dicing equipment, and sales increased for both
  - Laser equipment progressed to being an application that supports materials that are not suited for blade dicing
- It is difficult for a new process (plasma dicing) to completely exterminate the others



Summary

- Blade dicing is a stable process with many past results
  - It can be applied to a wide range of applications and devices
- Laser dicing was developed to handle high-performance semiconductors
  - By combining blade and laser, the applicable devices increased
  - Some areas that are not suited for blade dicing are covered by laser alone
- Plasma dicing makes it possible to achieve damage-less processing
  - However, many obstacles exist for the application of plasma dicing
  - For stable processing, combination with laser is being considered
- Demands for versatile blades will continue in the future as well

KKM for Power Devices

- From wafer making to device manufacturing -

DISCLAIMER

Statements in this PowerPoint with respect to DISCO's current strategies, plans, estimates, and beliefs and other statements that are not historical facts are forward-looking statements about the future performance of DISCO. These statements are based on management's assumptions and beliefs in light of the information currently available to it and therefore you should not place undue reliance on them. DISCO cautions you that a number of important factors could cause actual results to differ materially from those discussed in the forward-looking statements, and you should not make decision on your investment thoroughly based on these statements. Such factors include, but not limited to, (i) general economic conditions and levels of demand in DISCO's markets; (ii) developments in technology and resulting changes in semiconductor and/or electronic component manufacturing process; (iii) levels of capital investment for manufacturing semiconductors and/or electronic components; (iv) expansions of the area for products and technologies using semiconductors and/or electronic components and its expanding speed; (v) DISCO's ability to continue to offer products and services corresponding to developments of new semiconductors and/or electronic components and new technologies for manufacturing them; (vi) exchange rates, particularly between the yen, the U.S. dollar, and the euro, and other currencies.

©DISCO CORPORATION All rights reserved

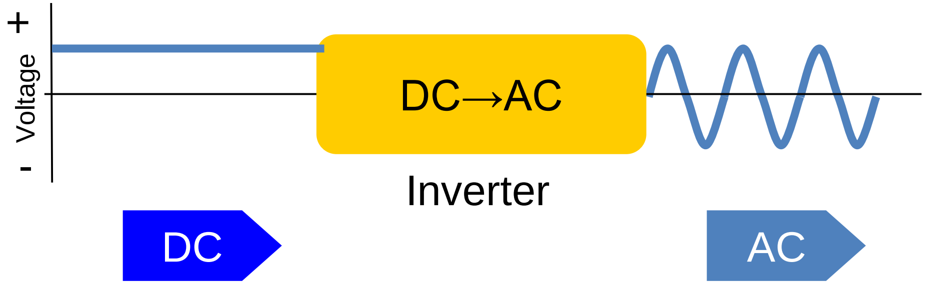
Agenda

- What is a power device?
  - Types/market
  - Difference from general-purpose IC
  - Advantages of SiC
- DISCO’s KKM for power devices
  - Solutions for Si
    - Wafer making
    - Device thinning: TAIKO®
  - Solutions for SiC
    - Wafer making: KABRA
    - Device thinning
    - Device singulation: Ultrasonic dicing, Stealth Dicing

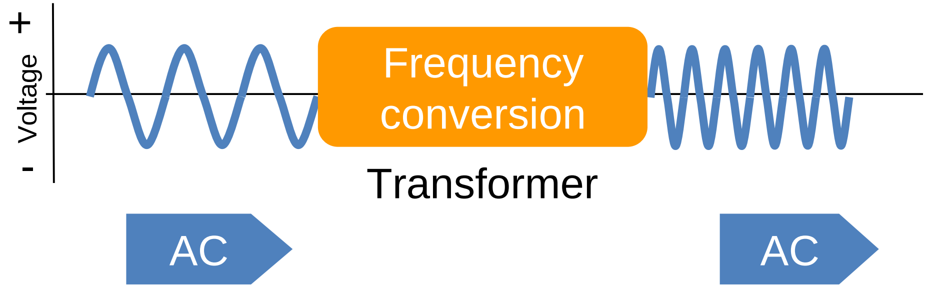
TAIKO is a registered trademark of DISCO Corporation in Japan and other countries.

What is a Power Device? - Types

- Power devices are semiconductor electrical components used for power control
  - DC ⇔ AC conversion inverter/converter
  - Amplification element, step-up/ step-down element



Inverter

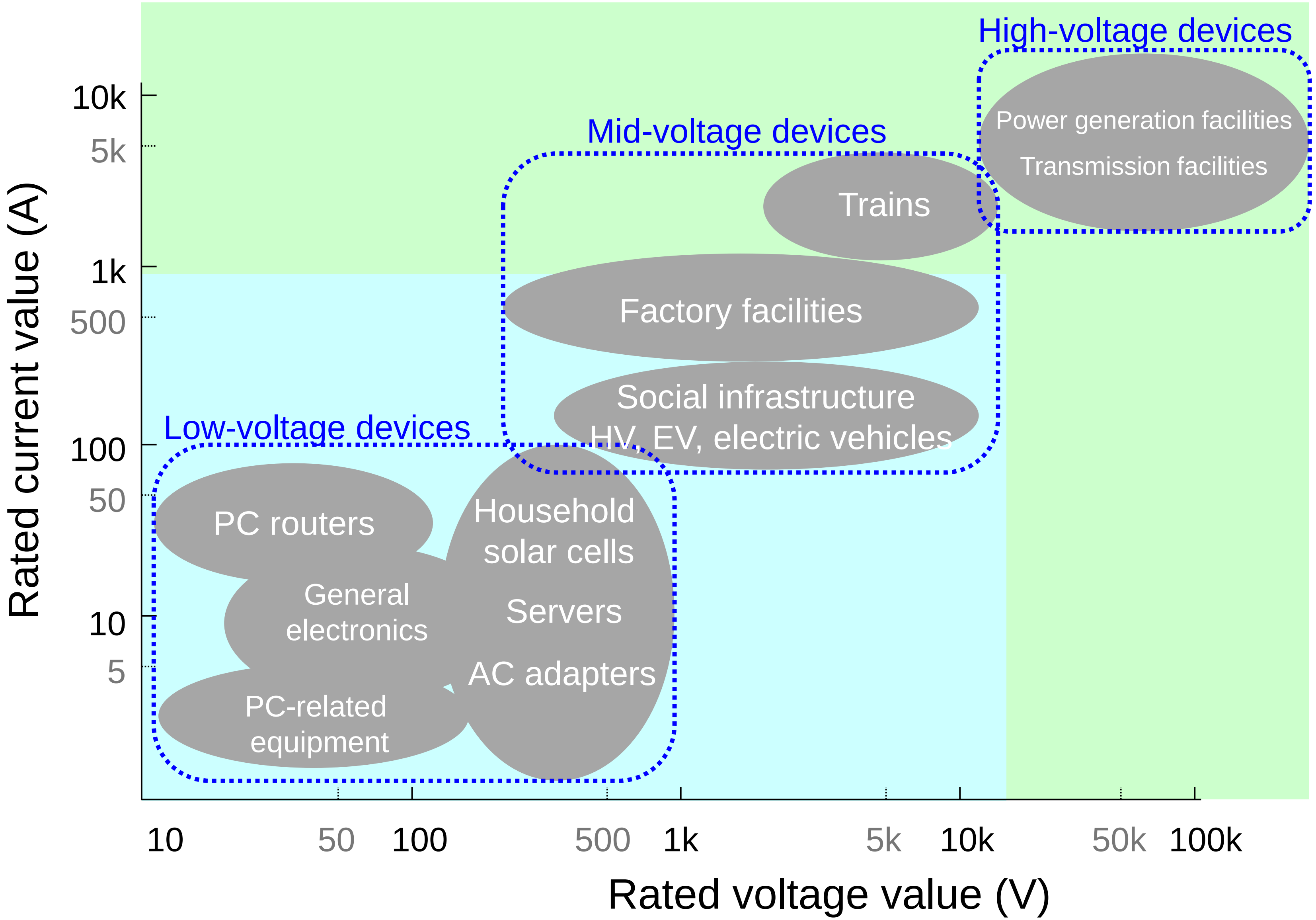


Transformer

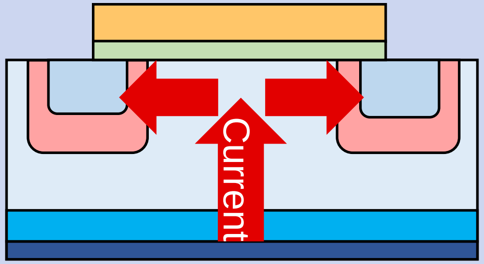
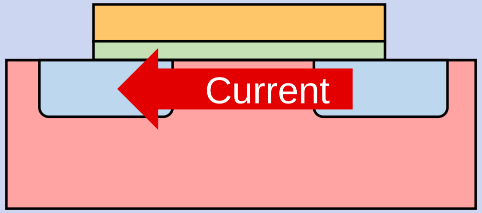
Converter

Regulator

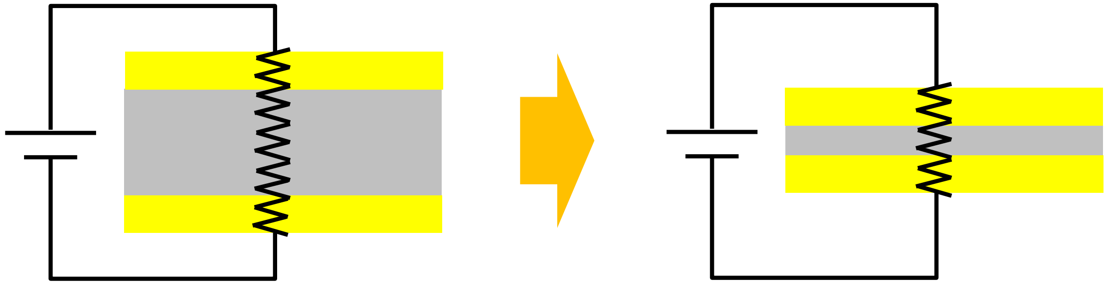
What is a Power Device? - Market



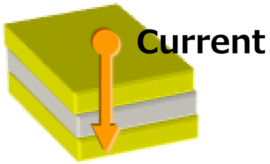
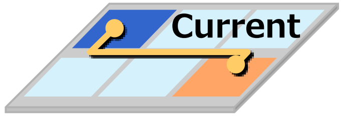
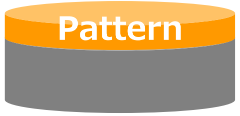
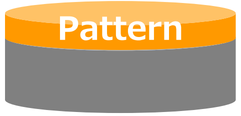
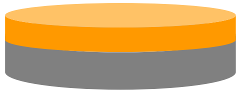
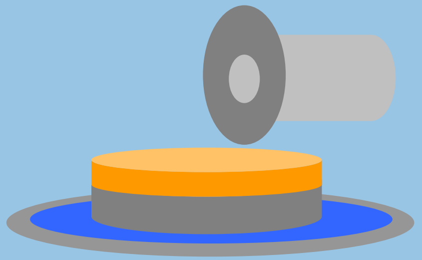
What is a Power Device? - Difference from General-purpose IC

	Power device	General purpose IC
Function	Power control	Data processing
Structure	Vertical structure  	Horizontal structure 
Reason for thinning	Reduction of internal resistance	Final product thinning and die stacking

- Reason for thinning: reduction of internal resistance
  - Reduced power loss
    Output Power = V^2 / R, or larger
  - Faster switching speed

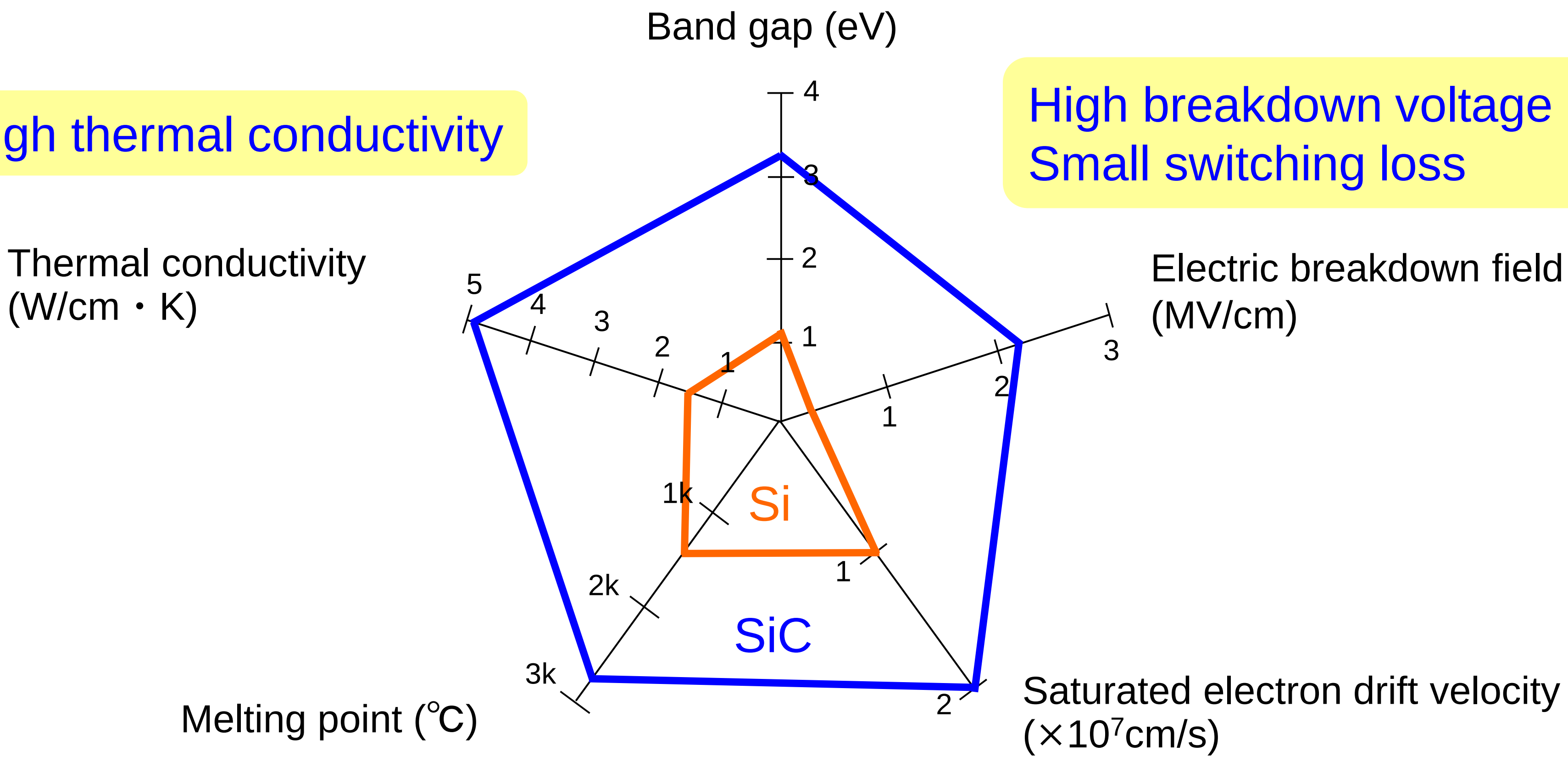


What is a Power Device? - Difference from General-purpose IC

	Power device		General purpose IC	
Structure	Vertical		Horizontal	
Processing method	Substrate (Si, SiC, etc.)		Substrate (Si)	
	Front-end process		Front-end process	
	Substrate thinning		Substrate thinning	
	Backside process (metal deposition, etc.)			
	Singulation			

Advantages of SiC

- SiC surpasses Si in the following characteristics, especially in having high voltage resistance



High thermal conductivity

High breakdown voltage
Small switching loss

High melting point, hardness

High electrical drift frequency

Agenda

- What is a power device?
  - Types/market
  - Difference from general-purpose IC
  - Advantages of SiC

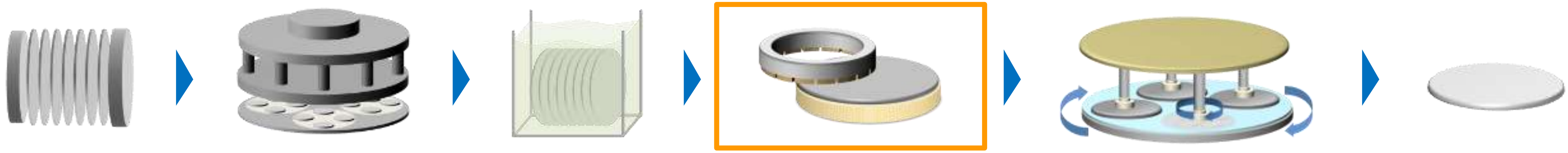
- DISCO’s KKM for power devices
  - Solutions for Si
    - Wafer making
    - Device thinning: TAIKO®
  - Solutions for SiC
    - Wafer making: KABRA
    - Device thinning
    - Device singulation: Ultrasonic dicing, Stealth Dicing

TAIKO is a registered trademark of DISCO Corporation in Japan and other countries.

Si Wafer Making

- DISCO’s KKM for Si wafer making

[Example of the general process flow (not limited to power devices)] *The process differs depending on the manufacturer


Ingot slicing
Lapping
Etching
Grinding
Polishing

  - High-precision, small-volume grinding ⇒ Reduced load in the next process and improved flatness of the final wafer using shape adjustment

- Change in wafer diameter for power devices
  - NAND memory chip size: 10 mm x 10 mm, relatively large
    ⇒ 300 mm wafers are common in order to increase the number of die per wafer
  - The chip size of power devices is relatively small (few mm x few mm)
    ⇒ 8 inch wafers used to be mainstream, but 300 mm wafers are starting to increase

Calculated with

・8 inch wafer
10 mm x 10 mm approx. 270 die
1 mm x 1 mm approx. 2,700 die

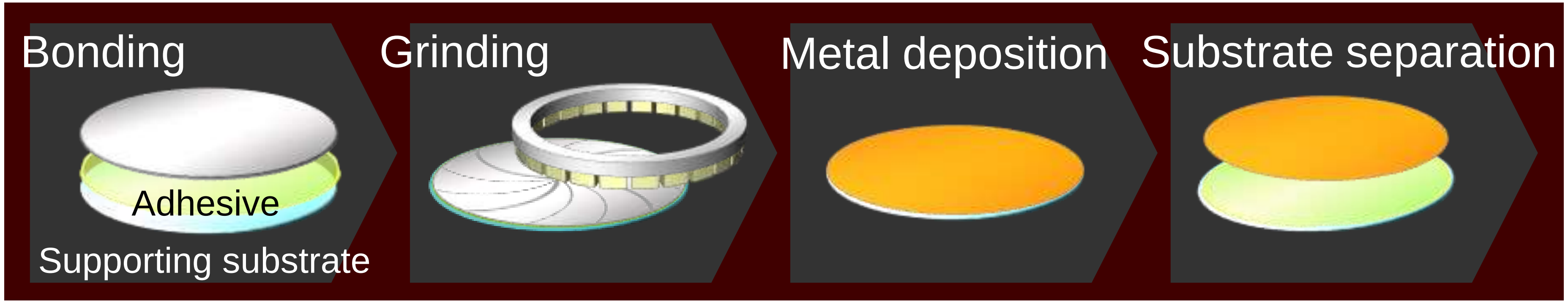
・300 mm wafer
10 mm x 10 mm approx. 640 die
1 mm x 1 mm approx. 6,200 die

Edge exclusion 2 mm
Street width 50 µm

Device Thinning: TAIKO®

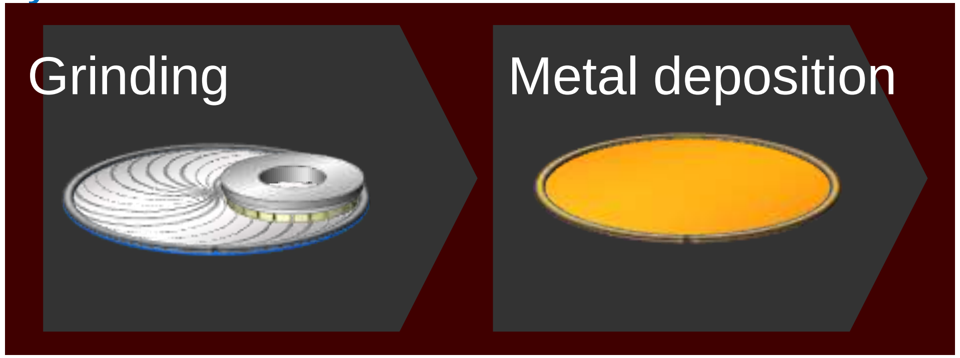
- Easy wafer handling is required for power devices due to the backside process after thinning.

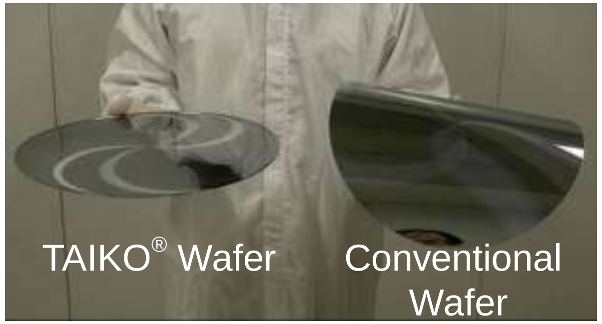
[Hard substrate method]



- Increased costs due to additional materials, outgassing due to high-temperature processes such as metal deposition

[TAIKO®] A technology that leaves an edge area on the outermost circumference of the wafer and grinds only the inner circumference to make it thinner





φ300 mm×50 µm

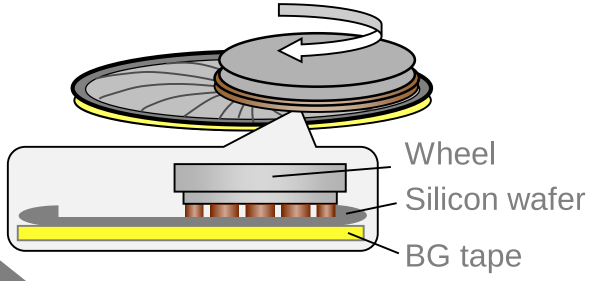
Reduced handling risk of thin wafers

- Improved wafer strength
- Reduced wafer warpage

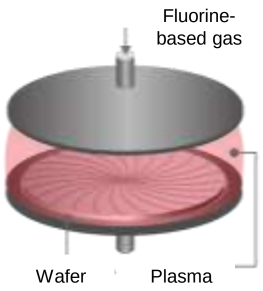
Device Thinning: TAIKO®

BG tape lamination

TAIKO® grinding



Stress relief Dry/wet

Dry etching	Wet etching
	

BG tape peeling

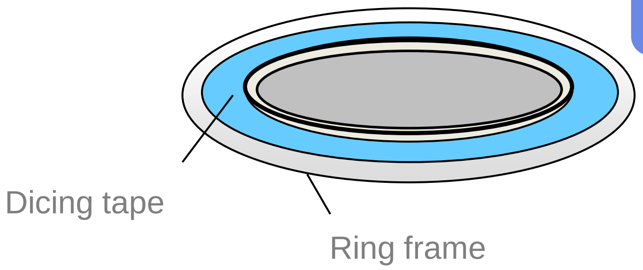
Backside process

- Ion implantation
- Annealing
- Backside metal deposition
- Wafer testing, etc.

Dicing tape mounting

Ring removal

Dicing



TAIKO is a registered trademark of DISCO Corporation in Japan and other countries.

Agenda

- What is a power device?
  - – Types/market
  - – Difference from general-purpose IC
  - – Advantages of SiC
- DISCO’s KKM for power devices
  - – Solutions for Si
    - Wafer making
    - Device thinning: TAIKO®
  - – Solutions for SiC
    - Wafer making: KABRA
    - Device thinning
    - Device singulation: Ultrasonic dicing, Stealth Dicing

TAIKO is a registered trademark of DISCO Corporation in Japan and other countries.

SiC Wafer Making: KABRA

- Conventional process (same as Si)

*The process differs depending on the manufacturer

Ingot slicing

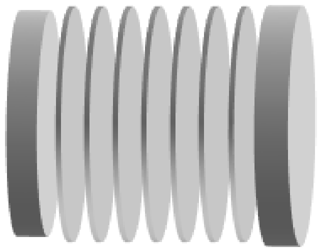
Lapping

Etching

Grinding

Polishing

  - Higher density and harder than Si ⇒ Lower productivity during processing and increased costs
  - Higher material cost than Si ⇒ Material loss during processing is an issue



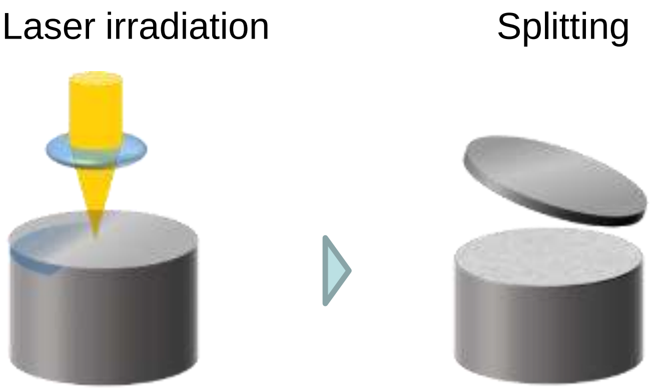
Ingot slicing: conventional process using a wire saw

Processing time: 100 hours (approx. 3.1 hours per wafer)
*When producing 350 µm thick wafers from a 6 inch, 20 mm thick ingot

Material loss: 180 µm
*The ratio of material loss is large for a wafer thickness of 350 µm

SiC Wafer Making: KABRA

- New SiC ingot slicing technology using laser
  - Significant reduction in processing time,1.4 times increase in wafer production volume

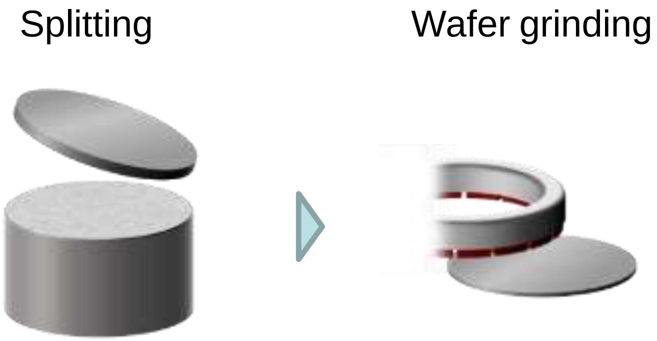


Processing time: 10 min per wafer (conventional: 3.1h)
*When producing 350 μm thick wafers from a 6 inch, 20 mm thick ingot

*When laser irradiation, peeling, and ingot grinding are done in parallel for multiple ingots

Material loss: 80 μm (conventional: 180 μm)
The number of wafers obtained per ingot is 1.4 times that of the conventional process

  - No lapping process necessary

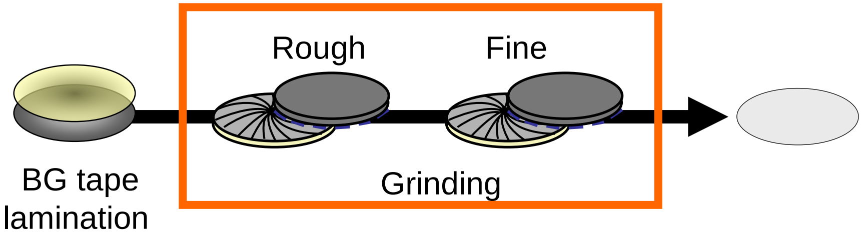


Conventional:
Lapping is necessary to remove wafer undulation caused by wire saw

KABRA:
Wafer undulation can be suppressed, so lapping is unnecessary

SiC Device Thinning

- Various processes according to processing quality and productivity
  - 2-axis grinding


Rough
Fine
BG tape lamination
Grinding

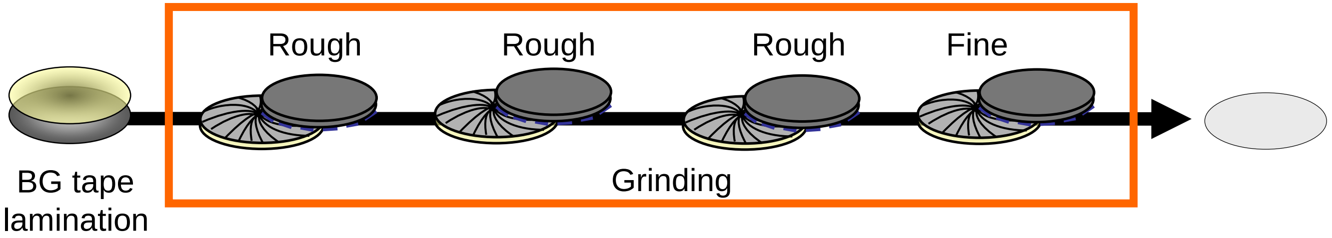
DFG8540
General-purpose 2-axis grinder

High-power spindle for SiC grinding

DFG8640
High-precision 2-axis grinder

Optimized processing point layout and installation of various functions make high-precision grinding, including SiC, possible

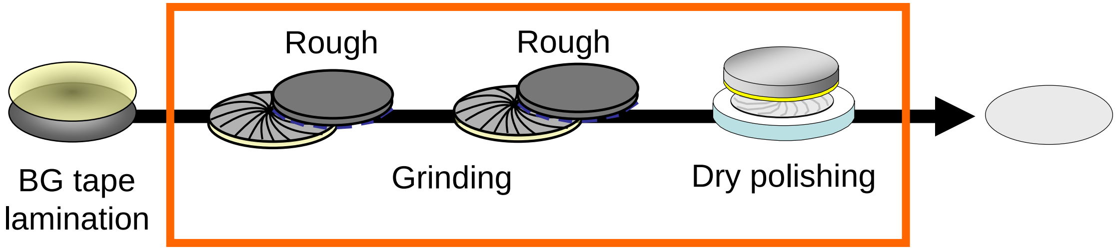
  - UPH improvement with 4-axis grinding


Rough
Rough
Rough
Fine
BG tape lamination
Grinding

DFG8830
4-axis grinder

Improved productivity by mounting optimal wheels on four axes

  - Quality improvement by dry polishing (DP)


Rough
Rough
BG tape lamination
Grinding
Dry polishing

DGP8761
Grinder/polisher with 2-axis grinding, 1-axis polishing

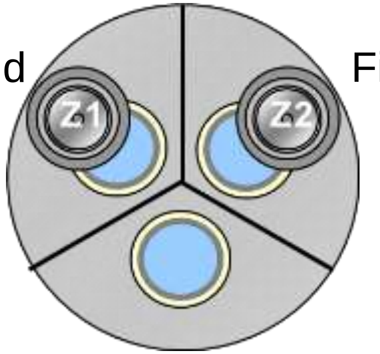
From thinning to polishing in a single unit

Device Thinning

- Improved productivity with 4-axis grinding

*The processing times are reference values and differ from the actual processing times

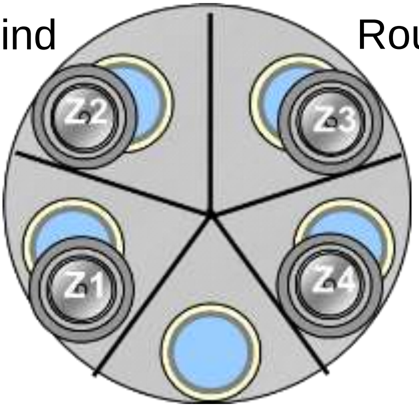
  - 2-axis grinding: rate determining time 400 s



Rough grind
400 s

Fine grind
200 s

  - 4-axis grinding: rate determining time 200 s



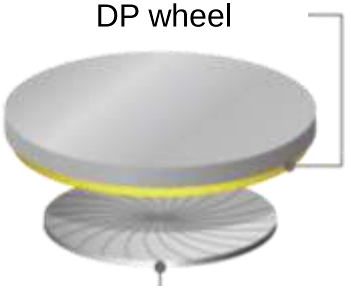
Rough grind
150 s

Rough grind
150 s

Rough grind
150 s

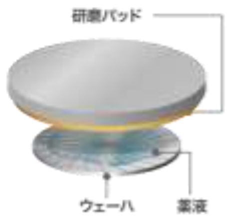
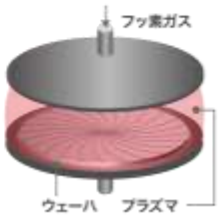
Fine grind
200 s

- Improved quality with dry polishing
  - DISCO’s original dry polishing
    - Environmentally friendly process that does not use water or slurry



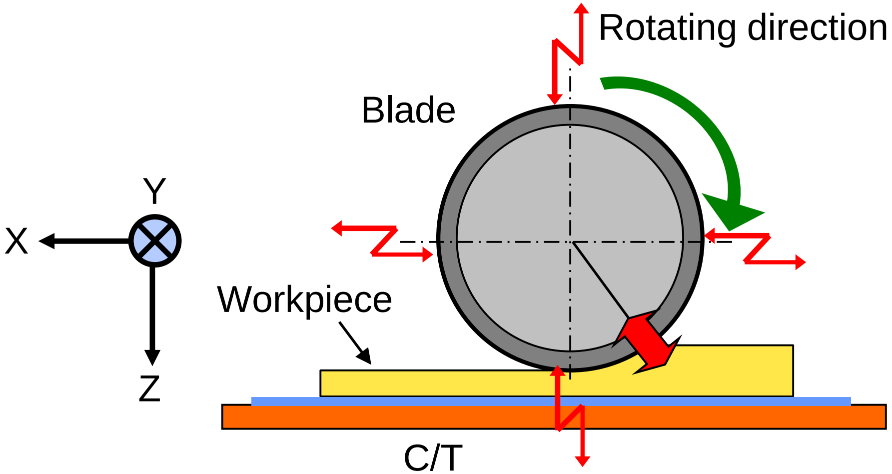
Removal of grinding damage
- Higher die strength
- Less wafer warpage

【Other polishing examples】

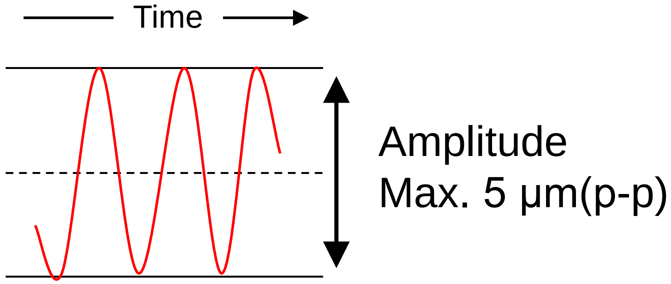
Wet polishing	Dry etching	Wet etching
		

SiC Device Singulation: Ultrasonic Dicing, Stealth Dicing

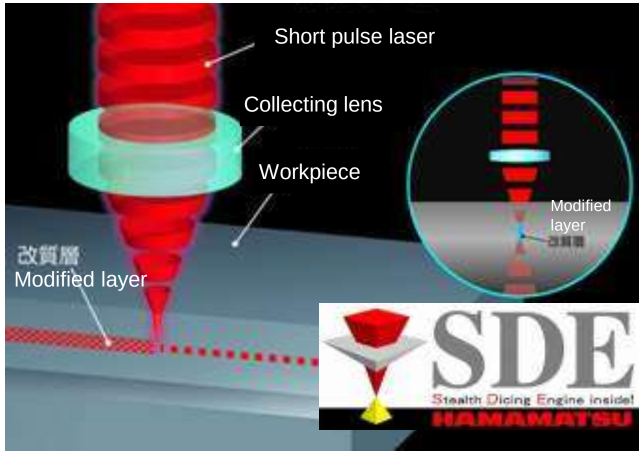
- UltraSonic (US) dicing
  - Improved processing speed and quality
  - Burr reduction for ductile materials

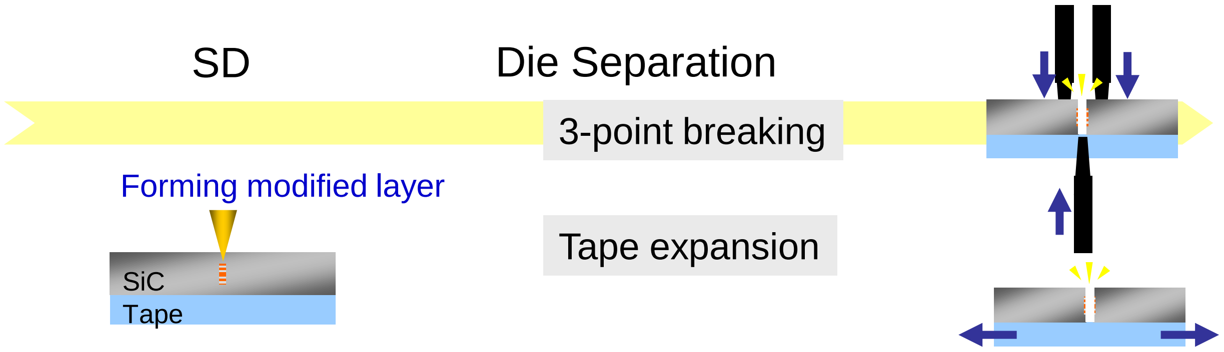


Amplitude of ultrasonic waves



- Stealth Dicing (SD)
  - Completely dry process that does not use water
  - High throughput processing using laser
  - Narrow kerf due to modified layer inside wafer



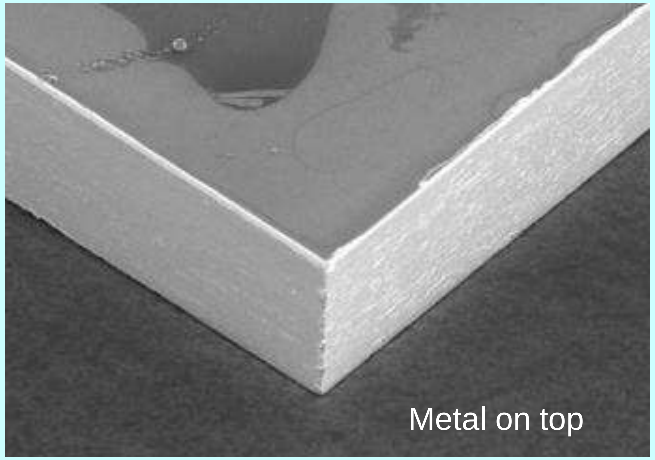


SiC Device Singulation: Ultrasonic Dicing, Stealth Dicing

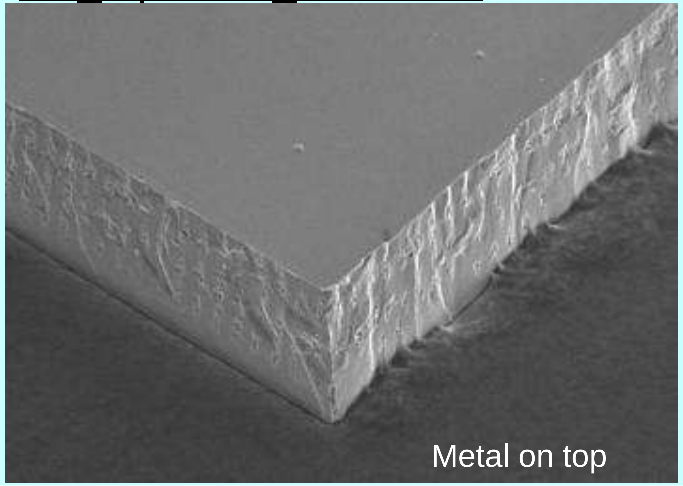
- Processing example: SEM photo, die strength

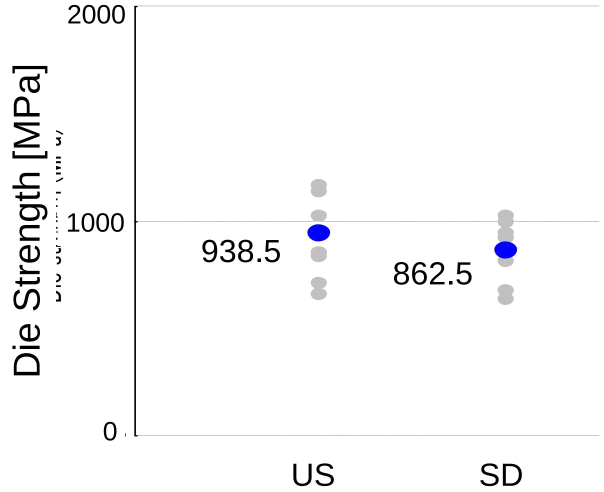
t = 110 µm

US_1 pass_10 mm/s



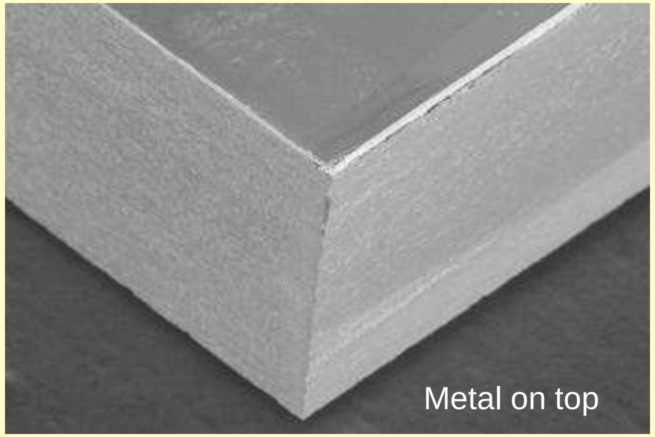
SD_3 passes_350 mm/s



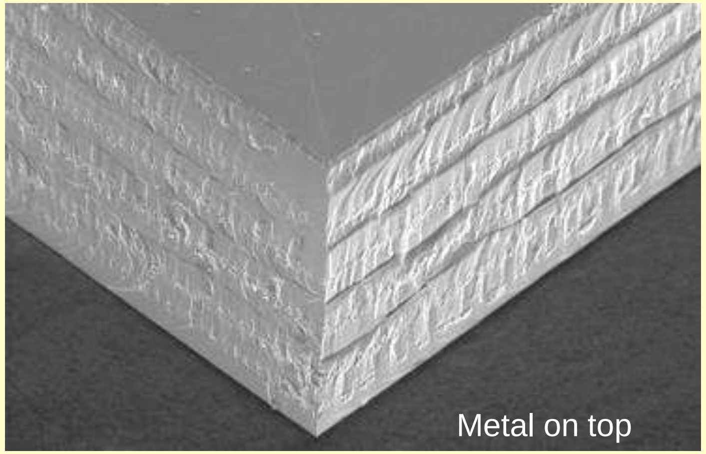


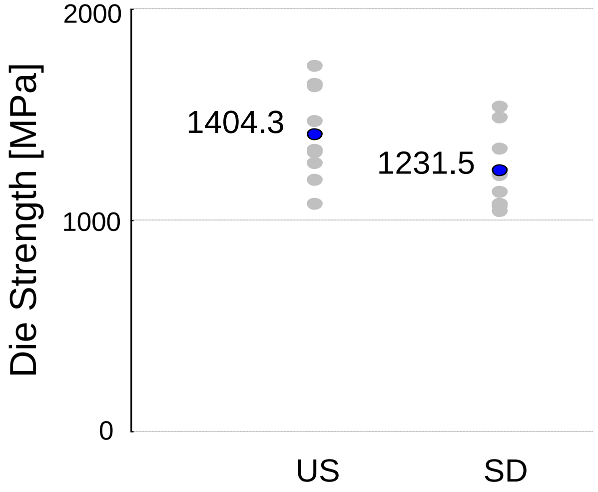
t = 350 µm

US_1 pass_10 mm/s



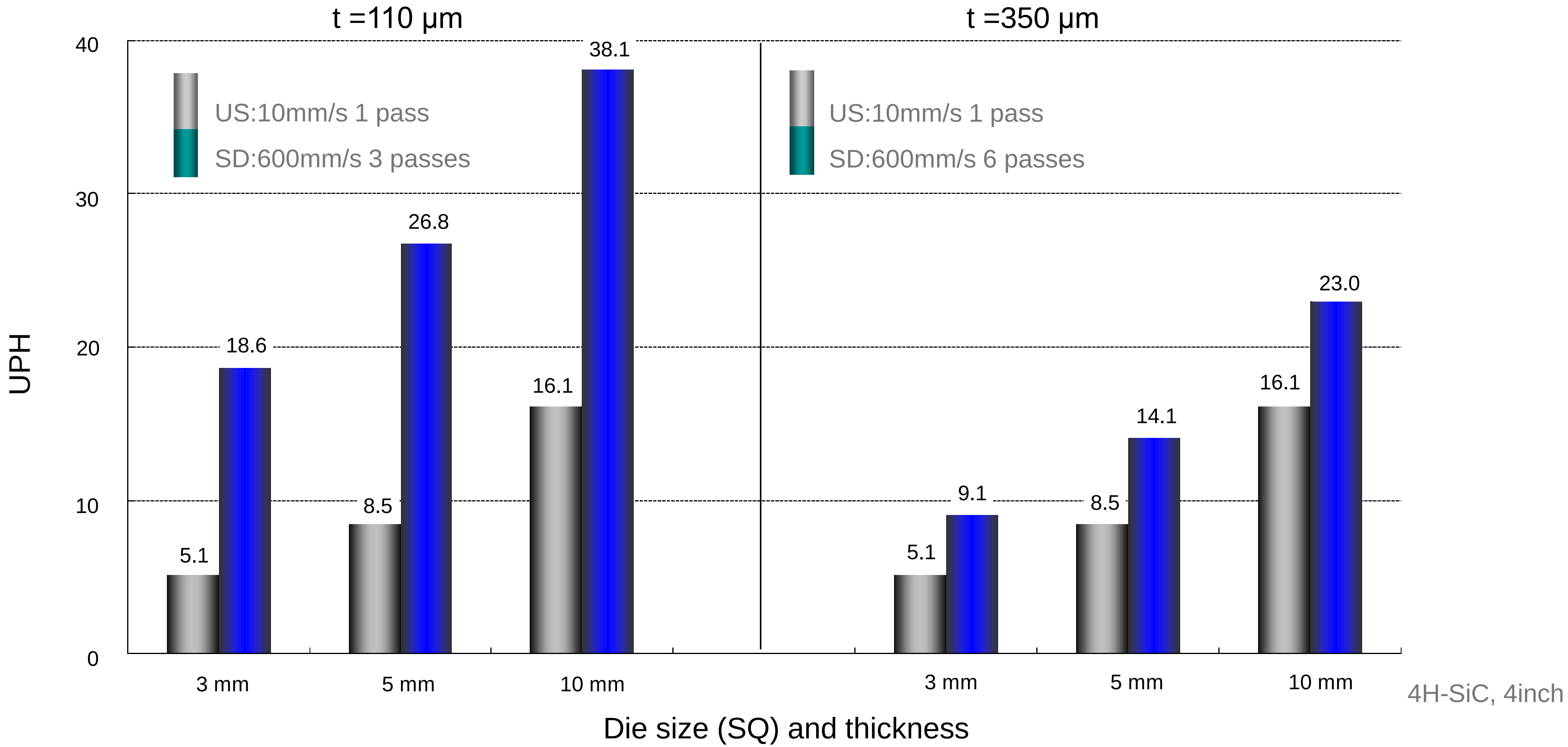
SD_6 passes_350 mm/s





SiC Device Singulation: Ultrasonic Dicing, Stealth Dicing

- UPH comparison



The UPH of SD depends on the thickness, so thinner substrates and smaller die sizes are advantageous

DISCO

Kiru·Kezuru·Migaku Technologies