# Solutions for thinning, dicing and packaging of power devices made of Si, Sapphire, SiC and GaN Nov. 7th, 2013

DISCO HI-TEC EUROPE GmbH

Gerald Klug, Nov. 2013

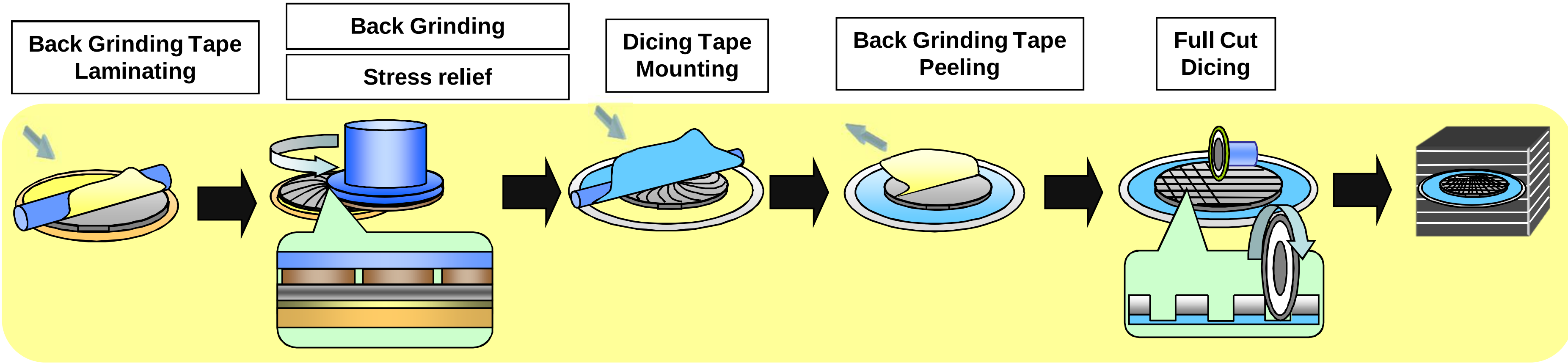
# AGENDA

- Thinning
  - New grinding wheels and dry polishing pad for SiC
  - Sapphire on frame grinding
  - 4-spindle grinder
  - Ultra-sonic grinding
  - Mini-TAIKO
- Various Dicing Technologies
  - Ultra-sonic dicing
  - Stealth dicing
  - Ablation laser
- Via-hole laser
- Planarization
  - Cu-Cu-bonding
  - Planarization of grinding tape for little TTV

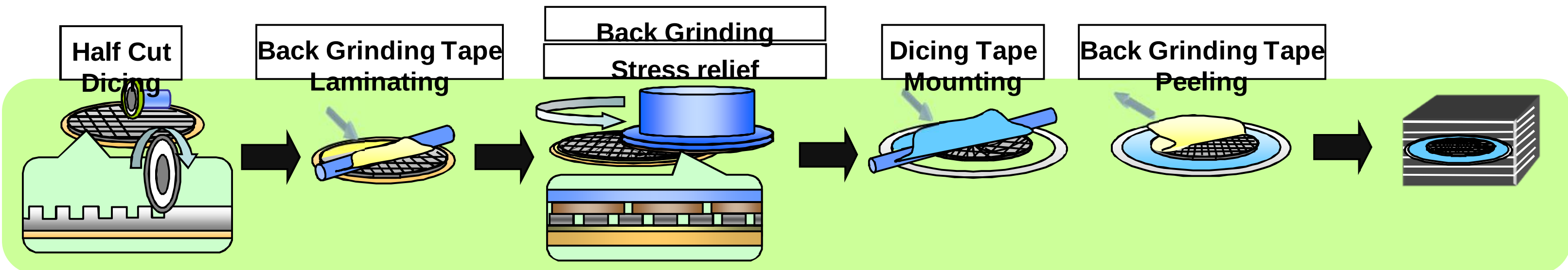
# Thinning by conventional process using new wheels



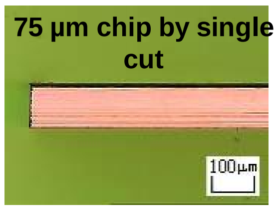
## Conventional Process



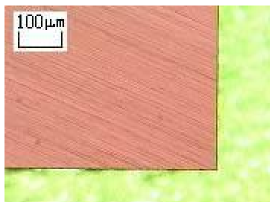

## DBG Process



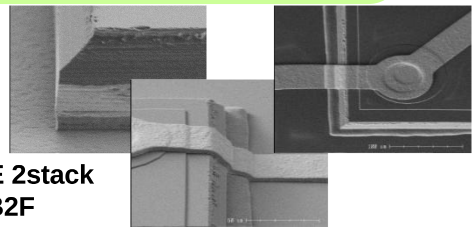

Die separation by back grinding




Topsi
de




Backsi
de

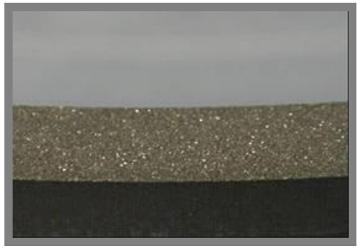
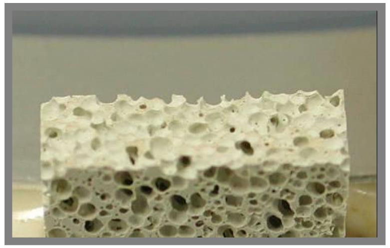


3DICE 2stack
B2F

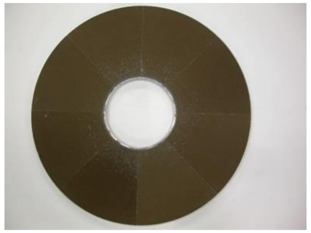
# SiC Grinding by GS08 and Dry Polishing



- Roughness: much finer than commonly used wheel for SiC

| SD1000-V462 | GS08-SE0126 (#3000) | GS08-SE0135 |
|---|---|---|
|  |  |  |
| Ra: 0.026 μm Ry: 0.296 μm | Ra: 0.011 μm Ry: 0.115 μm | Ra: 0.001 μm Ry: 0.009 μm |

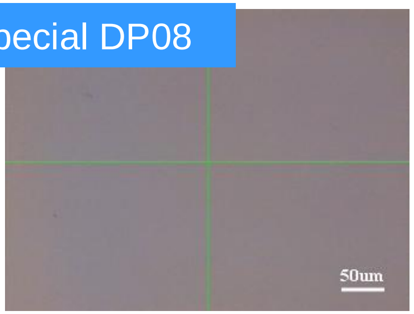
- **Dry Polish wheel for SiC**
  - Modified pad from standard Si polishing pad
  - Polishing for C plate side of SiC wafer



Grinding by #3000


Ra: 0.009 μm Ry: 0.063 μm

Special DP08

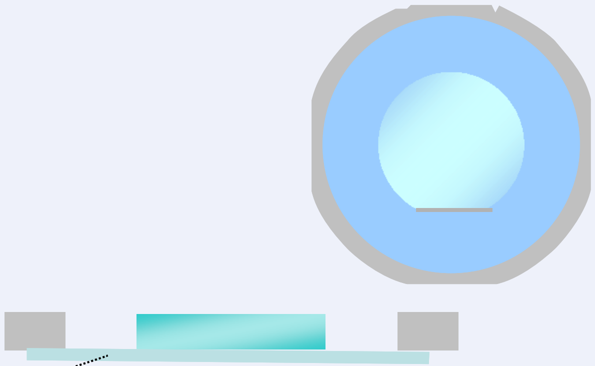



Ra: 0.001 μm Ry: 0.010 μm

# Sapphire Device Maker Status Update



- There are two thinning methods in fixing sapphire wafers.

| Method | Fixing on Substrate | Fixing on Ring Frame |
|---|---|---|
| Adhesive | **Wax** | **Tape** |
| How it looks like |  6 inch Sapphire wafer<br>Wax<br>8” Substrate, made by ceramics or etc. |  Tape<br>8” Ring frame (296 mm OD) |
| Tools | **DFG8830** | **DGP8761 (Frame grinding spec)** |
| Positive | **Easy of thinning**<br>・High fixing adhesive<br>・Stable wafer edge in thinning<br>・Rigid substrate | **Process advantage**<br>・Automated process<br>・No chemical cleaning necessary (cleaned by water)<br>・No tape re-mounting (less process steps) |
| Negative | ・No automated process<br>・Wafer cleaning process after detached.<br>・Manual handling of Thinned wafer in cleaning<br>・Mounting on dicing frame | ・Rather weak in fixing<br>・Elastic tape material |

# Frame grinding: Handling of difficult to process workpieces

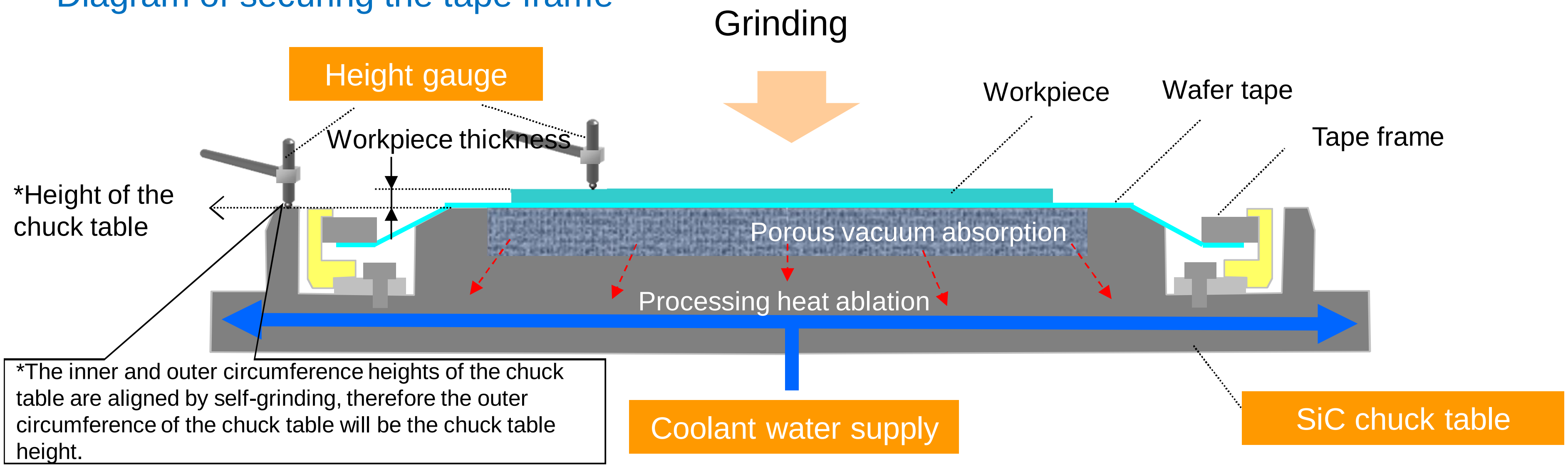


- Stable processing of workpieces with a tape frame
  - Clamps the tape frame and secure it.
  - Measures the thickness of the workpiece and the chuck table with the 2-probe height gauge and control them with a high degree of thickness accuracy in real time.
- Efficiently eliminating processing heat and handling high load processing
  - SiC chuck table with high thermal conduction
  - Supply the coolant water to the inner part of the chuck table

Chuck table

Difficult workpiece examples
•Sapphire
•SiC
•$Al_2O_3TiC$ (Altic)

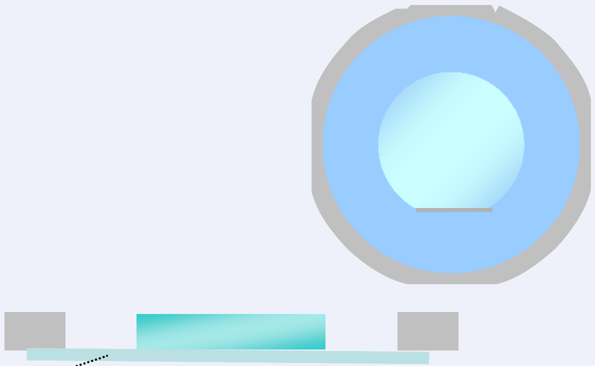
## Diagram of securing the tape frame



# Sapphire Device Maker Thinning Process by DFG8330



- There are two thinning methods in fixing sapphire wafers.

| Method | Fixing on Substrate | Fixing on Ring Frame |
|---|---|---|
| Adhesive | **Wax** | **Tape** |
| How it looks like | <br>8” Substrate, made by ceramics or etc. | <br>8” Ring frame (296 mm OD) |
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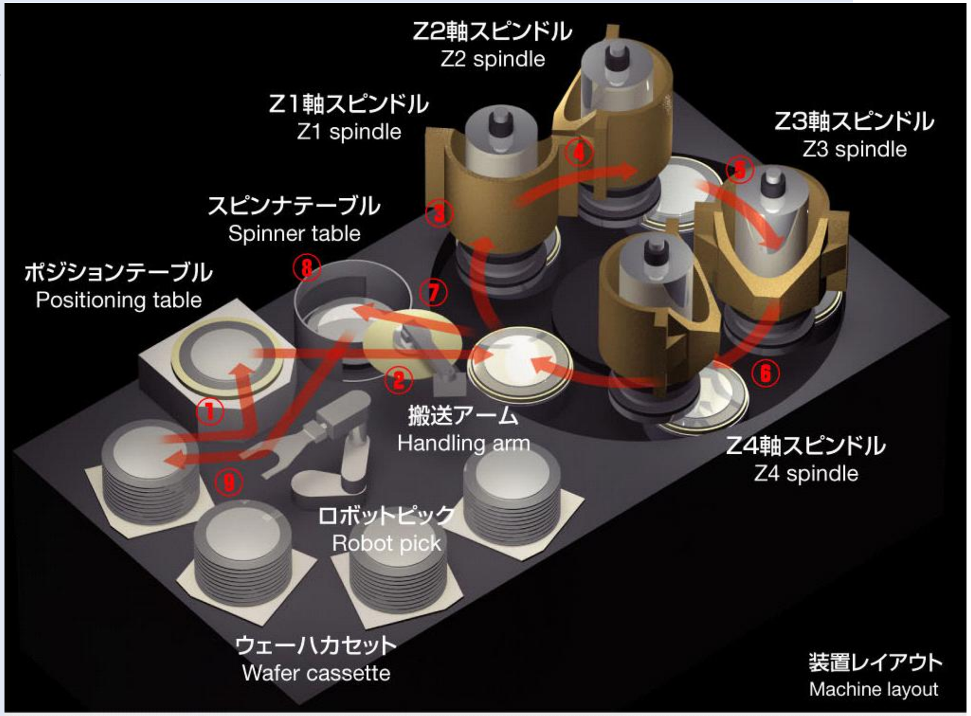
| Negative | ・No automated process<br>・Wafer cleaning process after detached.<br>・Manual handling of Thinned wafer in cleaning<br>・Mounting on dicing frame | ・Rather weak in fixing<br>・Elastic tape material |

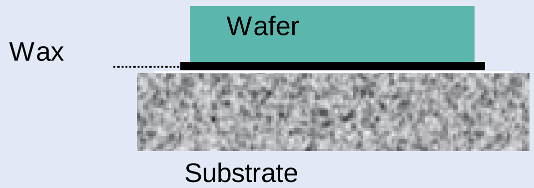
# DFG8830 Equipment Overview



- 4 axes (grinding process) with 5 chuck tables
- 4 cassette stages
- Small footprint
  - Bridge-type Z-axis structure
  - Optimized transport layout
- 6.3 kW spindle, for ø300 mm wheels
- Workpiece thickness: up to 3.5 mm
- Supported workpiece size: up to 8 inches
  - 6 inch wafer on 8 inch substrate




- Target throughput:
  - 6 inch sapphire 100um: UPH15
  - 4 inch sapphire 100um: UPH30

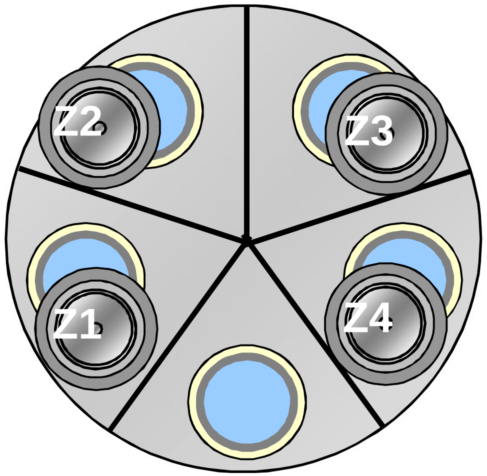



Machine dimensions（W×D×H）：1,400×2,500×2,000（mm）
Machine weight：approx. 6,000 kg

# SiC thinning process Application Example Φ6”

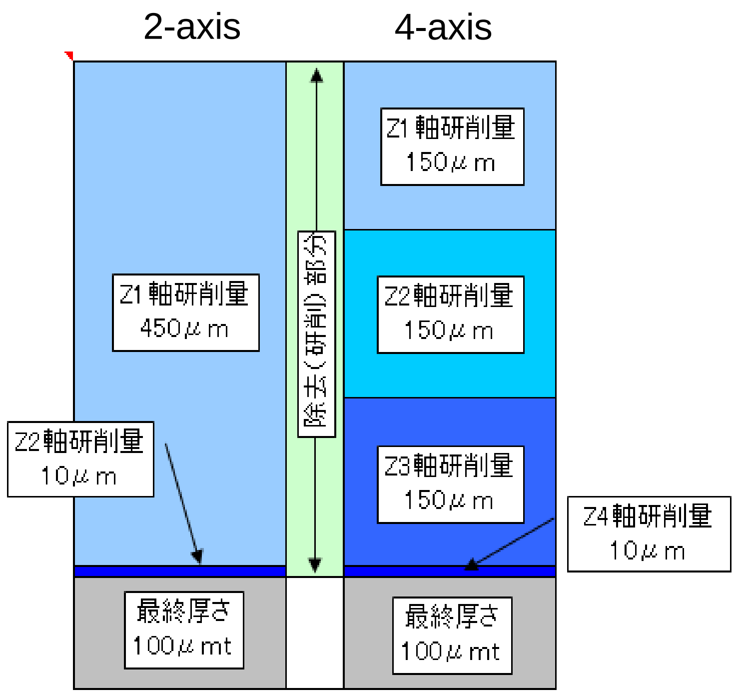


## φ6 inch ＳｉＣ wafer process example




- Ex) 560 μmt→ 100 μmt finish
- Z1,Z2,Z3 :#3000 **NEW**
- Z4 : Fine mesh

（ Wheel removal amount comparison ）




| | Z1 #3000* | Z2 #3000* | Z3 #3000* | Z4 Fine mesh |
|---|---|---|---|---|
| Grinding amt (μm) | 150 | 150 | 150 | 10 |
| Finish Thickness | 410 | 260 | 110 | 100 |
| UPH | 5 | | | |

***Equivalent to #3000**

# Sapphire Device Maker thinning 【Cost & UPH : DFG8830】

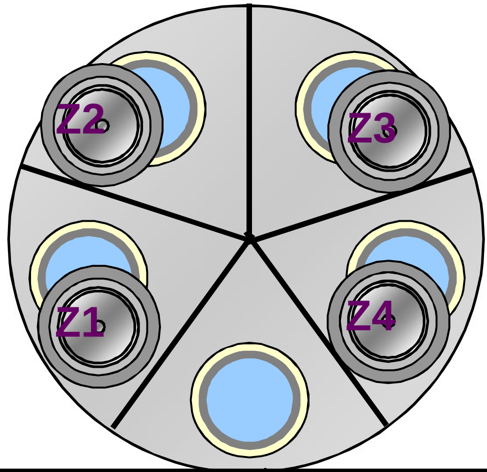


( Substrate fixed )

## Grinding sample

- Z4 wheel : "#1400" (or "**High-mesh**")

New:
High mesh wheel is now under development to make realize "lap-less" process



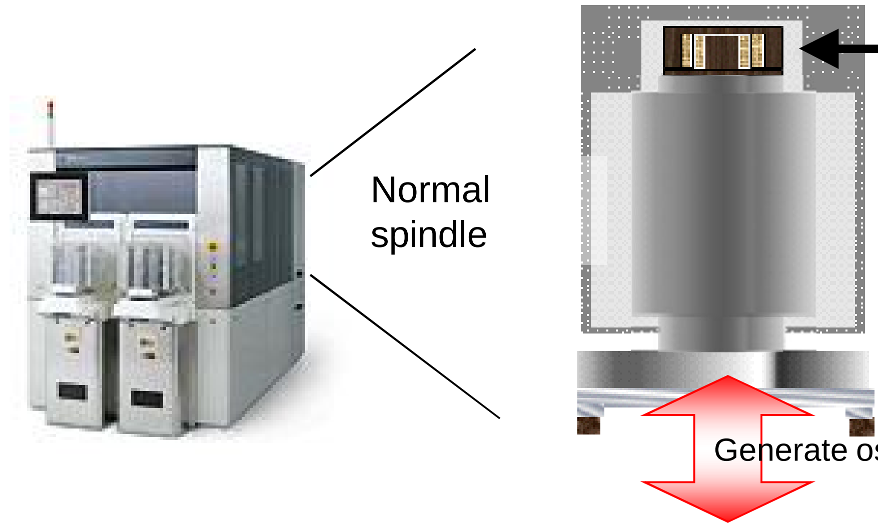

| Wafer size | Original thickness | Target thickness | Finish wheel | **UPH |
|---|---|---|---|---|
| Φ 4 inch | 900um | 100um | #1400 | 30 |
| | | | [High-mesh] | [18.5] |
| Φ 6 inch | 1300um | 140um | #1400 | 23 |
| | | | [High-mesh] | [12.5] |

* The index time is calculated in **10** seconds.
** Under development.
Not guaranteed values

# Ultrasonic grinding unit



- DISCO continue testing the advantage of US grinding




Main component parts for unit

Ultrasonic wheel

Ultrasonic oscillating circuit, power

Non contact power supply

Control software

# Effect of Ultrasonic grinding for sapphire

- φ4inch sapphire
- #320 Z1-axis grinding ->Lapping

- Ultrasonic grinding makes the affected layer shallower, it decreases lapping removal amount

Lapping removal amount in order to remove affected layer

## Ultrasonic – ON (feed speed : 5 μm/s)

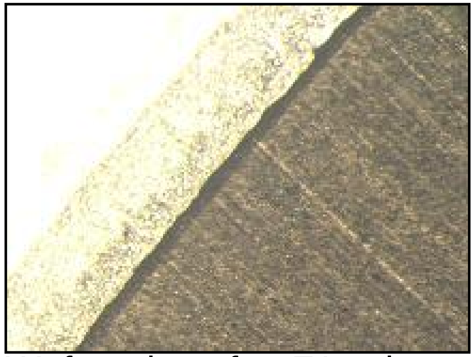

Wafer edge after Z1-axis grinding


After Z1-axis grinding

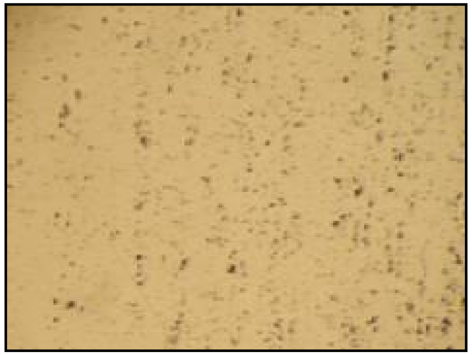

**After 15 μm** lapping


**After 27 μm** lapping

## Ultrasonic – OFF (feed speed : 5 μm/s)


Wafer edge after Z1-axis grinding


After Z1-axis grinding


**After 30 μm** lapping

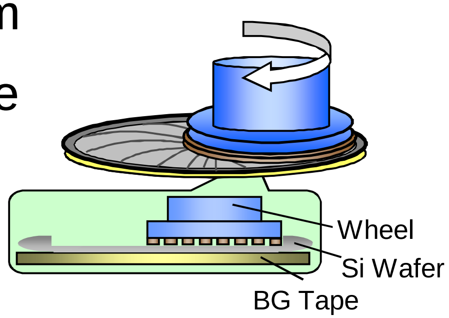

**After 40 μm** lapping

# TAIKO for SiC wafer (Mini TAIKO)



- Easier handling of thin wafer
  - Wafer support by the outer rim
    - Decreased wafer warpage
    - Improved strength

TAIKO Grinding




<u>Less warpage and higher wafer strength</u>

Picture: ϕ300 mm, 50 µm

- Processing 4inch　SiC wafer

**1-axis grinding**

#1000V401 wheel
- Spindle current: stable
- Grind amount: Wheel wear　1:1
- Roughness: Ra 40 nm

→ Stable but Ra needs to be improved

# Various Dicing Techniques



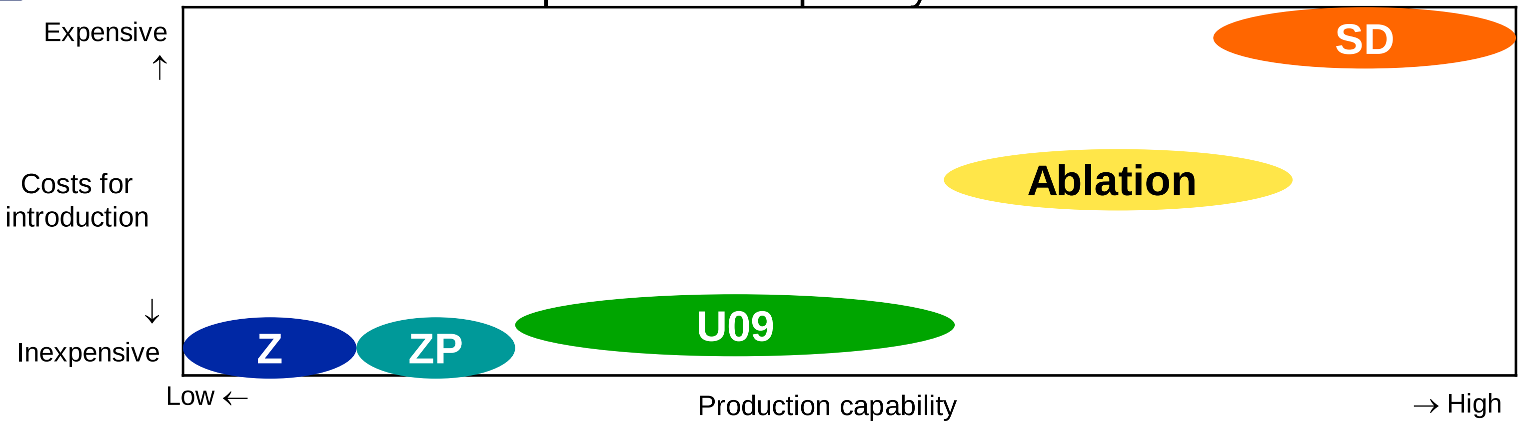
## Features

Assumptions

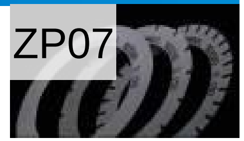
Monthly production volume: 3,000 ø4-inch wafers
Wafer thickness: 360 µm
Die size: 3 × 3 mm
Monthly operating hours: 576 hours

| | Blade Dicing | | | Laser Dicing | |
|---|---|---|---|---|---|
| | **Z** | **ZP07** | **U09 (Ultrasonic wave processing)** | **Ablation** | **SD** |
| Processing quality | Fair | Fair | Good | Very good | Super good |
| Feed speed | 2 mm/sec | 3 to 5 mm/sec | 10 to 20 mm/sec | 50 mm/sec | 30 mm/sec<br>150 mm/sec, 5 passes |
| CoO | Very good | Good | Super good | Good | Fair |
| Usage | R&D | | High volume production | (Under development) | R&D |

## Cost for introduction and production capability



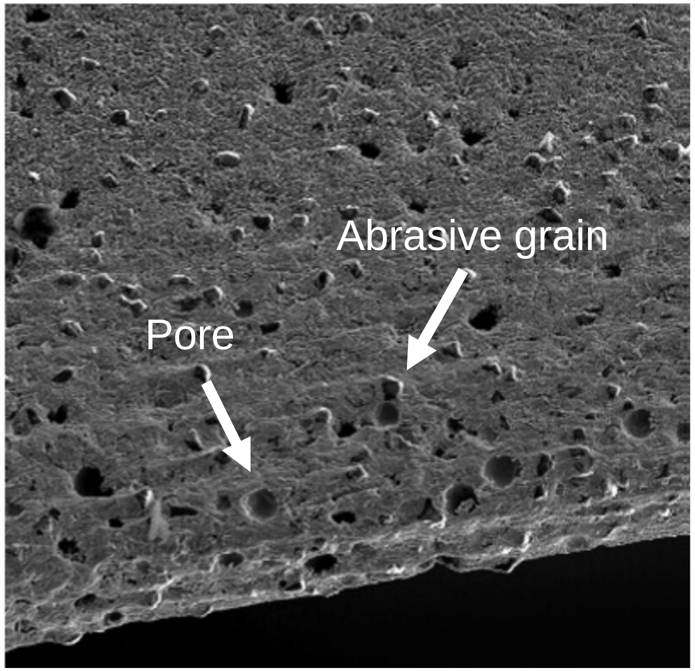
# ZP07 Series



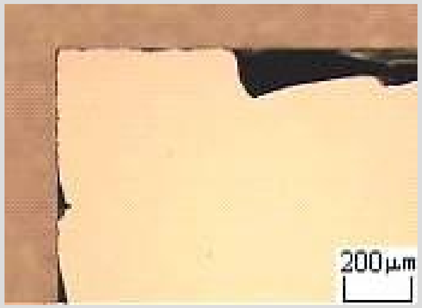
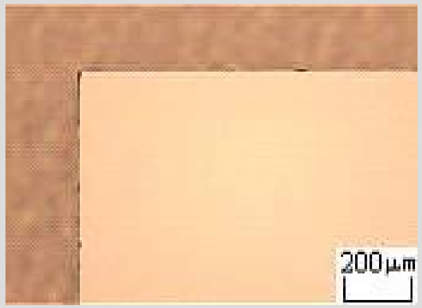

Enables high quality processing without additional capital investment.

- Less wavy cuts or risk of damage compared with Z
- Electroformed blades having a porous structure
  - Demonstrates high cutting ability by maintaining adequate self-sharpening effect thanks to pores in the bond.
  - Developed for hard and brittle materials, such as Si and glass bonded wafers. Enables processing of SiC.

SEM image of blade edge

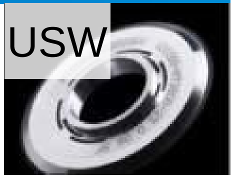



Difference in workpiece backside chipping

| Z | ZP07 |
| --- | --- |
|   |   |

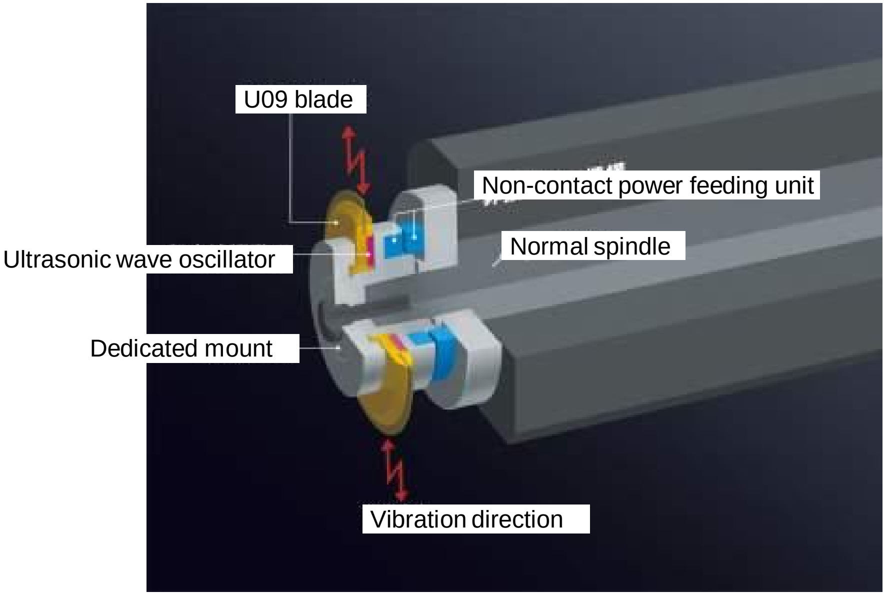
# Ultrasonic Wave Dicing

High-speed oscillation of the blade improves self-sharpening and flow of cutting water.

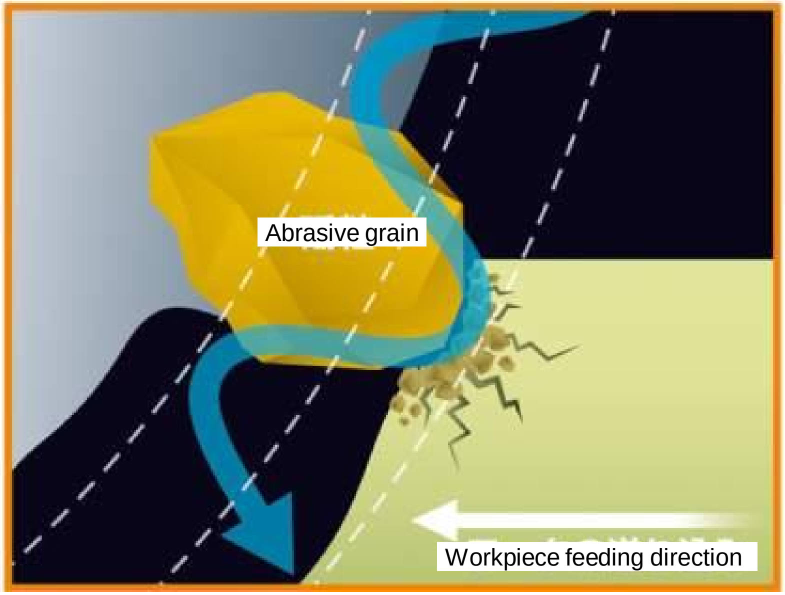



- Higher throughput
  - Higher feed speed
  - Less dressing frequency
- Higher processing quality
  - Less loading and glazing
  - Substantial reduction of blade breakage and wavy cutting

Mechanism

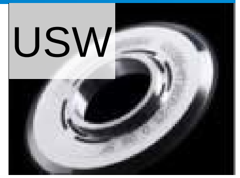



Processing point



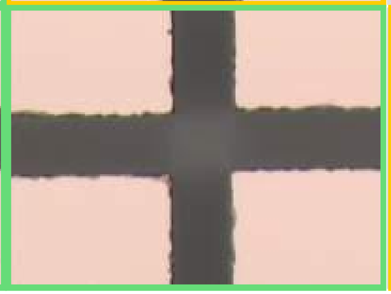
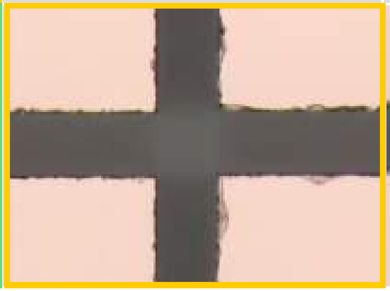
# Ultrasonic Wave Dicing: High Throughput






- Ultrasonic wave processing enables increasing the feed speed without deteriorating the processing quality.

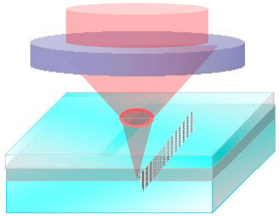
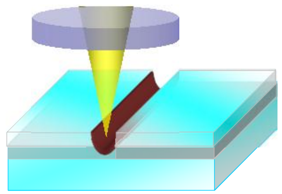
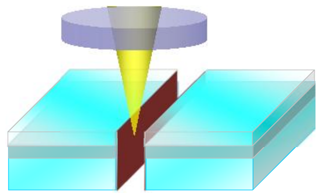
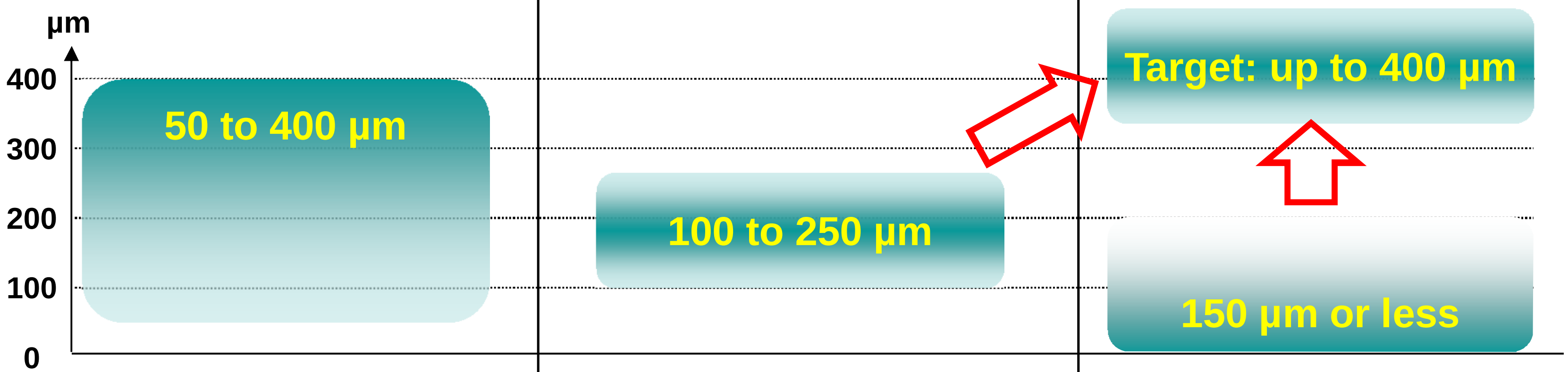
Backside chipping

| | 2 mm/sec | 5 mm/sec | 10 mm/sec | 20 mm/sec |
|---|---|---|---|---|
| Z |  |  |  | Blade breakage |
| ZP07 |  |  | Blade breakage | |
| U09 |  |  |  |  |

# SiC Laser processing methods



Under Development

| | Stealth Dicing (SD) | Ablation Process | |
|---|---|---|---|
| | | Scribing | Full Cut |
| Processing method |  Formation of a modified layer by focusing SD laser inside |  Grooving with short pulse laser |  Die separation by short pulse laser alone |
| Advantage | High quality processing with almost zero kerf width | High speed processing and die separation of thick wafers | Die separation with high throughput of thin wafers |
| Target wafer thickness |  | | |

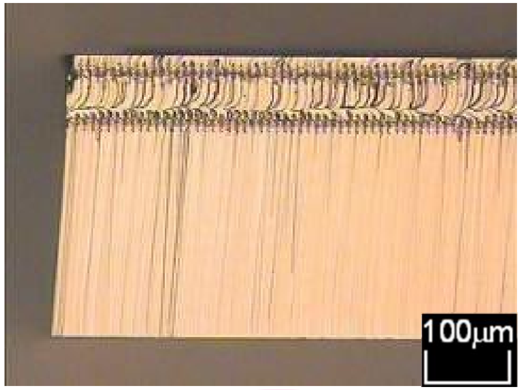
# Stealth Dicing (SD)



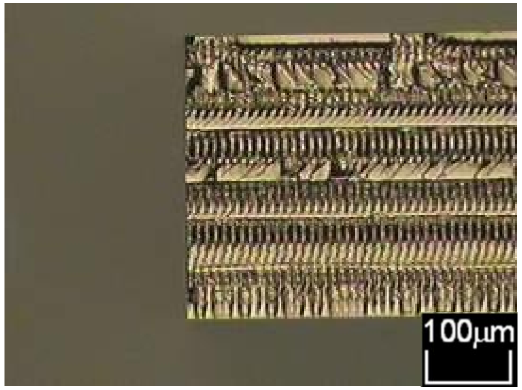
## Current processing quality

| Wafer thickness [µm] | Feed speed [mm/s] | Number of passes | Note |
|---|---|---|---|
| 360 | 150 | 2 to 6 | The number of passes can be changed depending on the required quality. |

**Processing example: Die cross-section after breaking**




**Equipment delivered in the past**



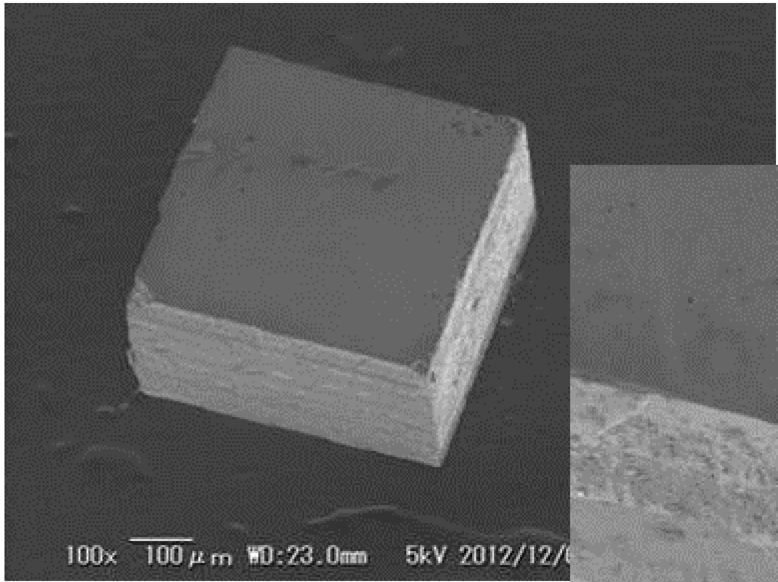

ø4” wafer

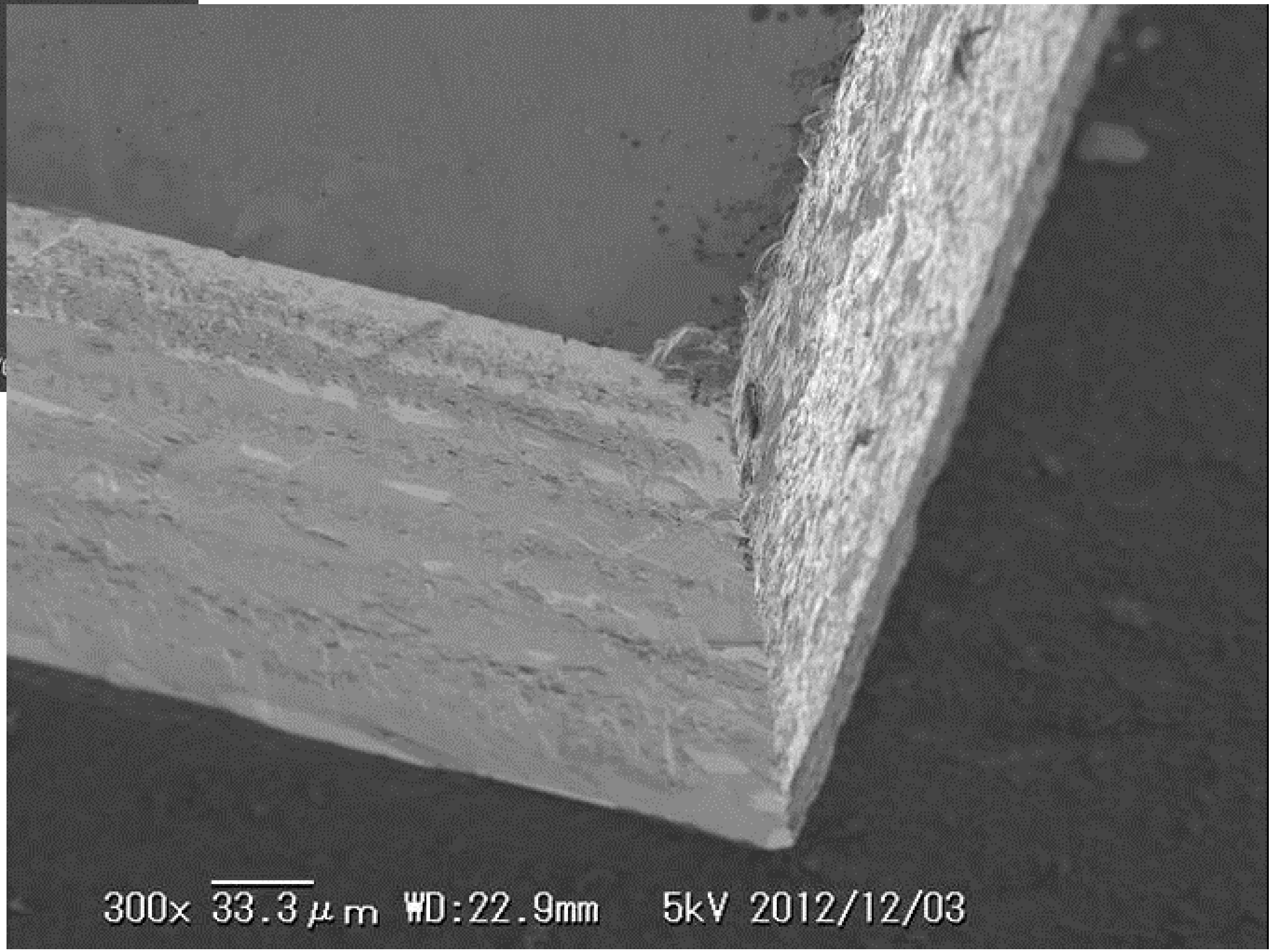
Index: 3.0 × 3.0 mm

**Number of passes: 2**
**UPH: 19.1**
**Slant cracks: 17 µm**

**Number of passes: 6**
**UPH: 9.2**
**Slant cracks: 0 µm**

# GaN (Stealth dicing) t500um




7 passes
270 mm/s

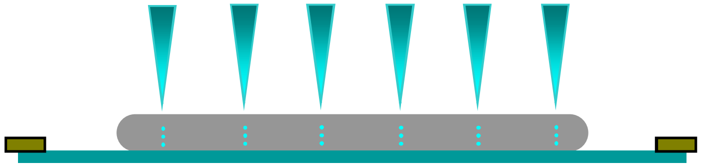
# Wafer Expander / Mounter (1/2)

Patent pending

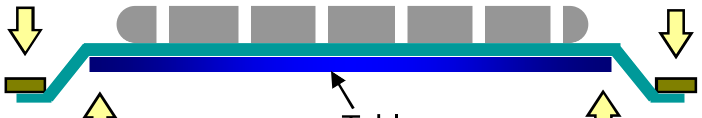
## Possible to re-mount on the same-sized ring frame

1) Wafer is mounted on a ring frame

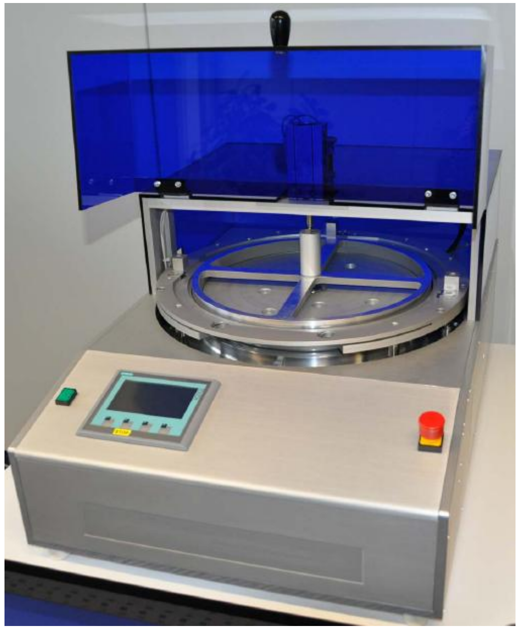
2) SD laser cut (from front side or backside)



3) Expand for die separation




Possible to re-mount
- 8 inch to 8 inch frame
- 12 inch to 12 inch frame



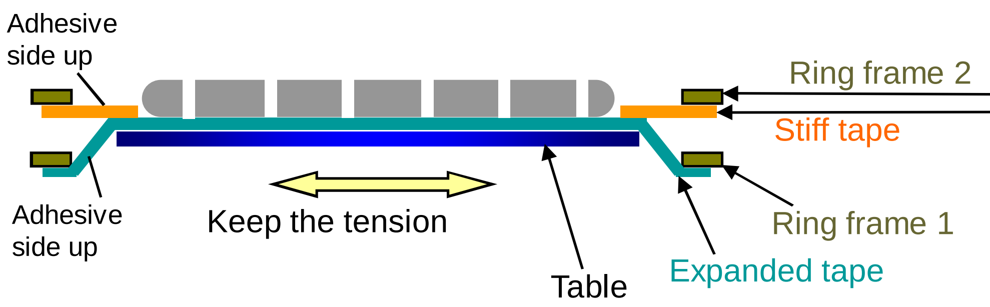
This method can also be used for standard dicing or DBG wafer.

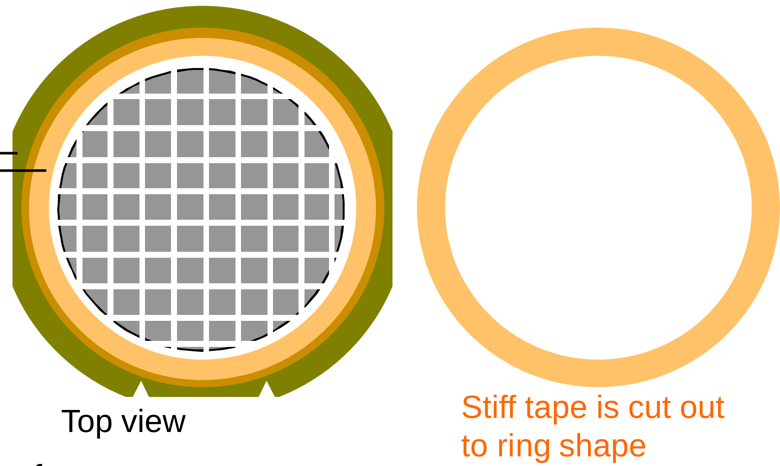
# Wafer Expander / Mounter (2/2)

Patent pending

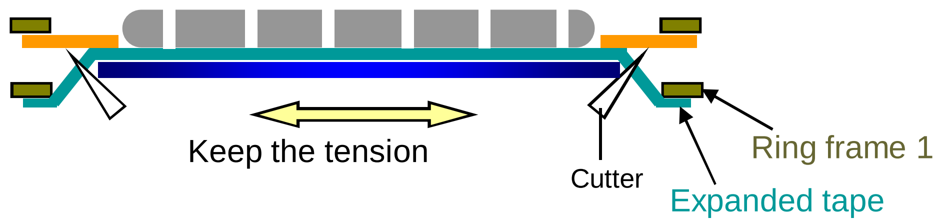


4) Mount stiff tape on ring frame 2 and cut out to ring shape.
Put it on expanded tape as below.

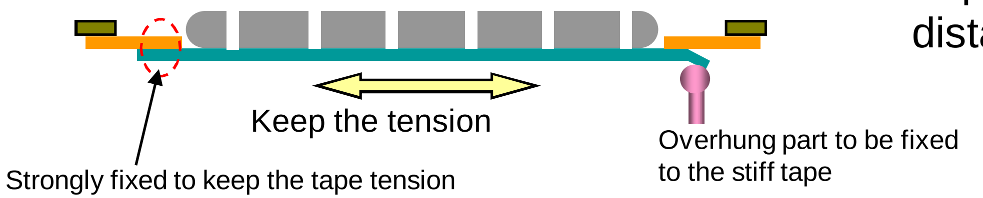



5) Cut out the expanded tape and remove the ring frame 1.




6) Finish




Expanded tape tension is kept, so die-to-die distance is stable.

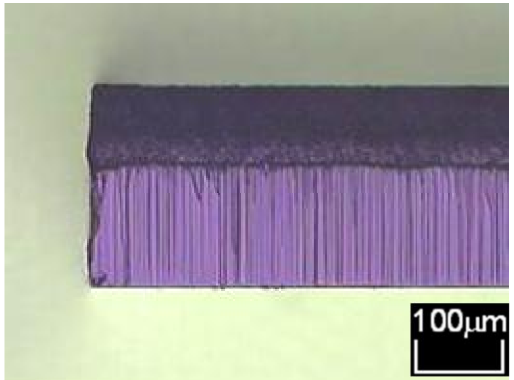
# Ablation Laser Scribing

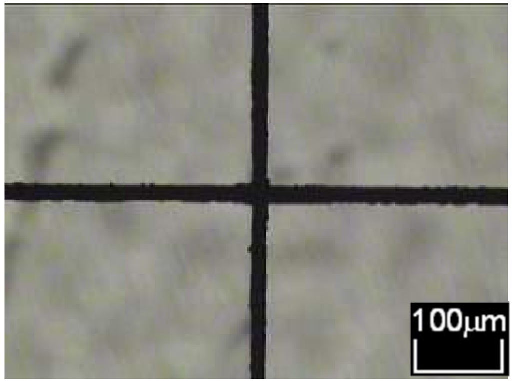


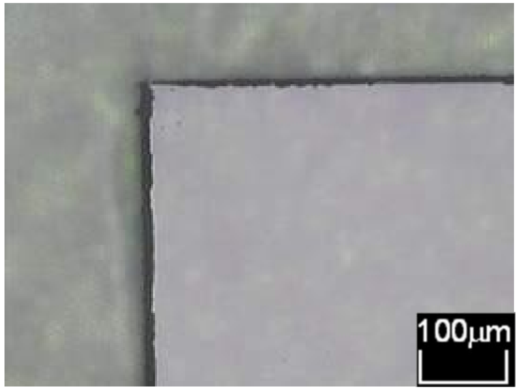
## Current processing quality

| Wafer thickness [μm] | Feed speed [mm/s] | Number of passes | Note |
|---|---|---|---|
| 250 | 50 | 1 | The cut depth can be changed depending on the ability to separate die. |

**Processing example: When processing with Type-D_BSS3**




**Processing depth: 103 μm**

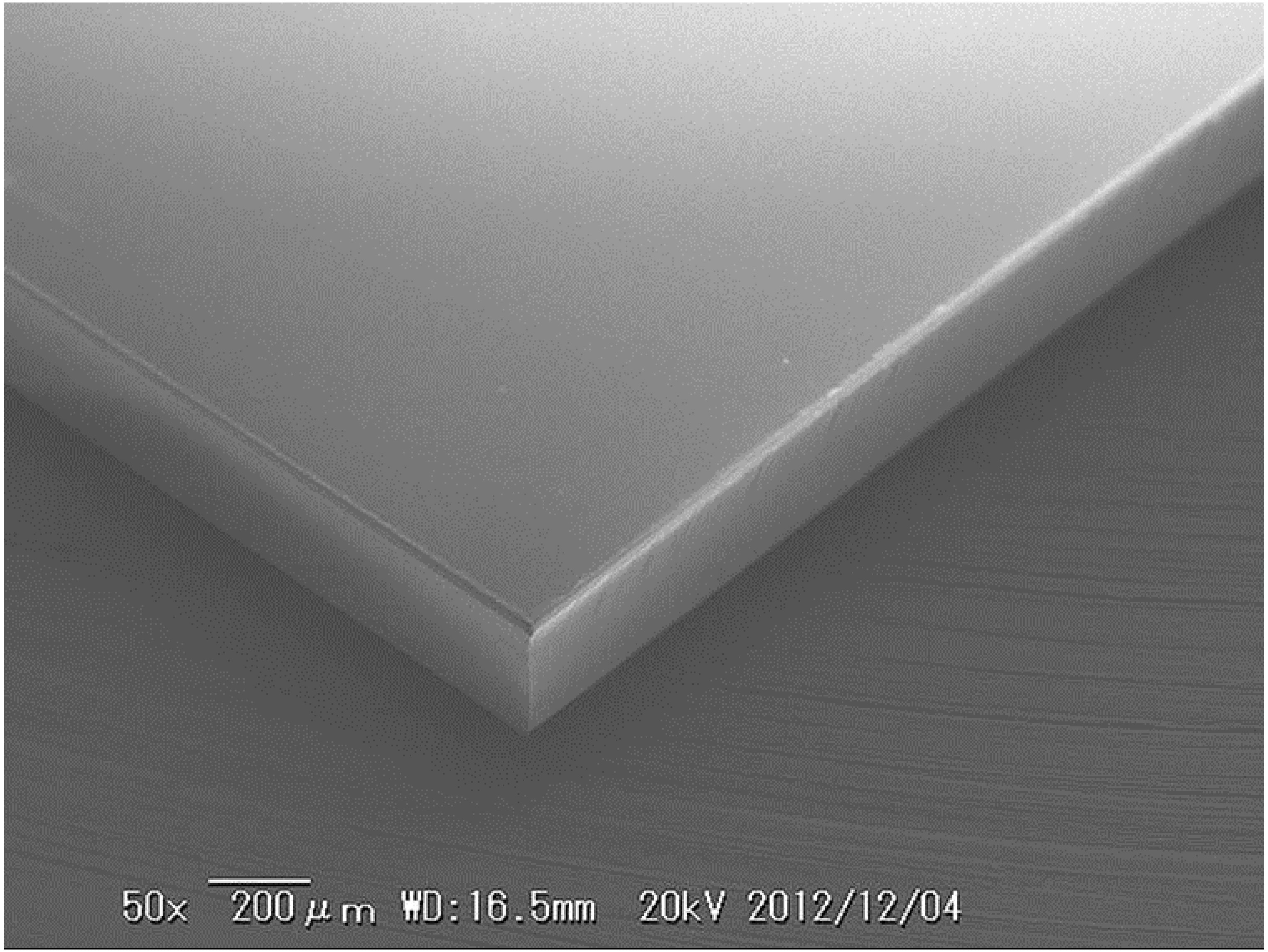
**Kerf width: 20.3 μm**

**No chipping**

**UPH: 17.4**

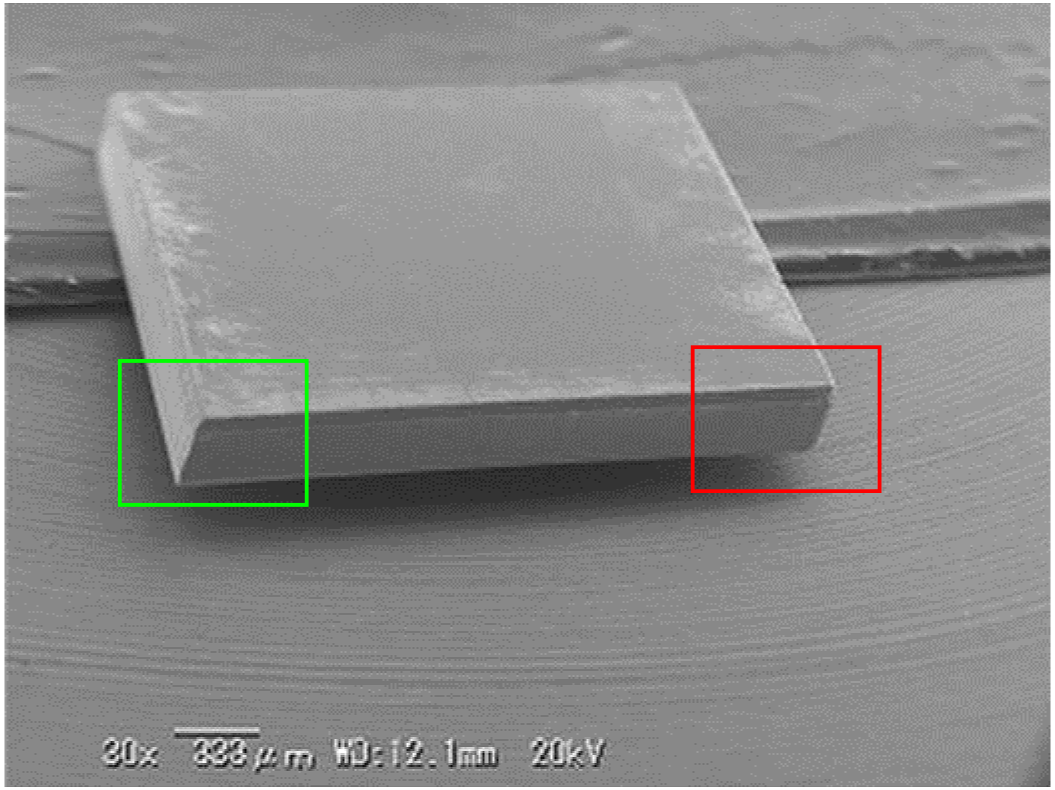
ø4” wafer
Index: 3.0 × 3.0 mm

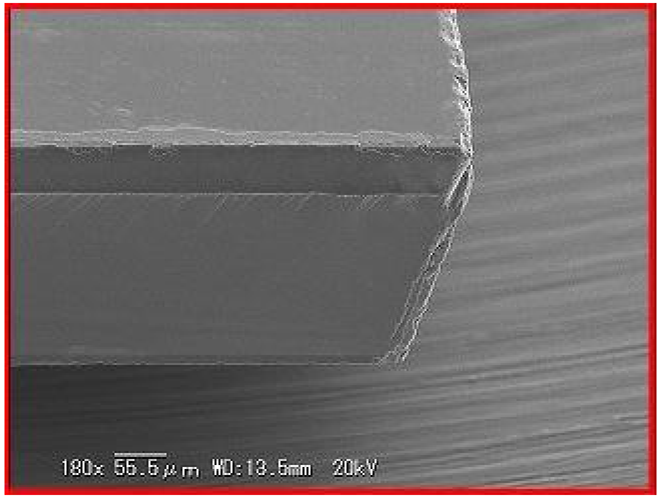
# Sapphire Stealth laser full cut t=300um

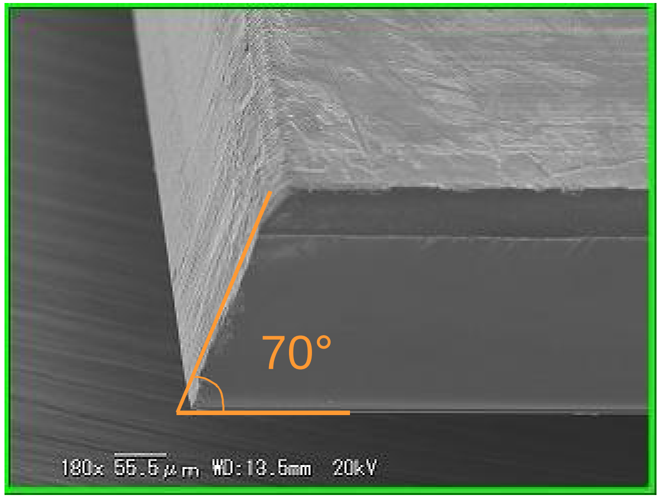


# Sapphire tilt shape t=300um



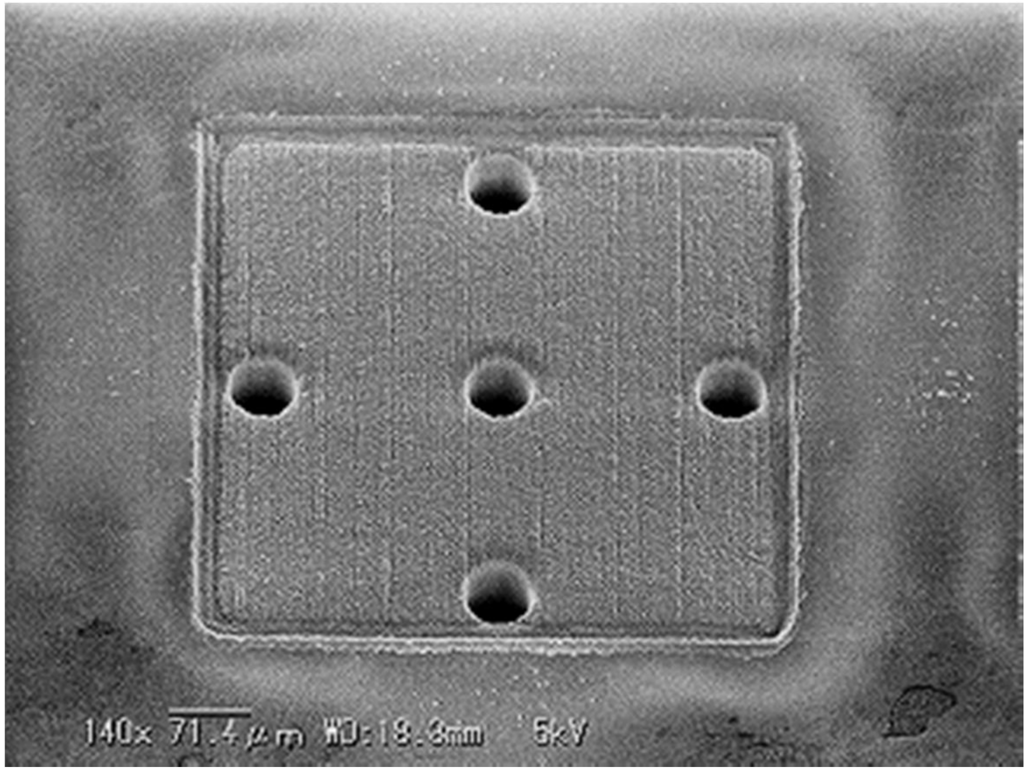


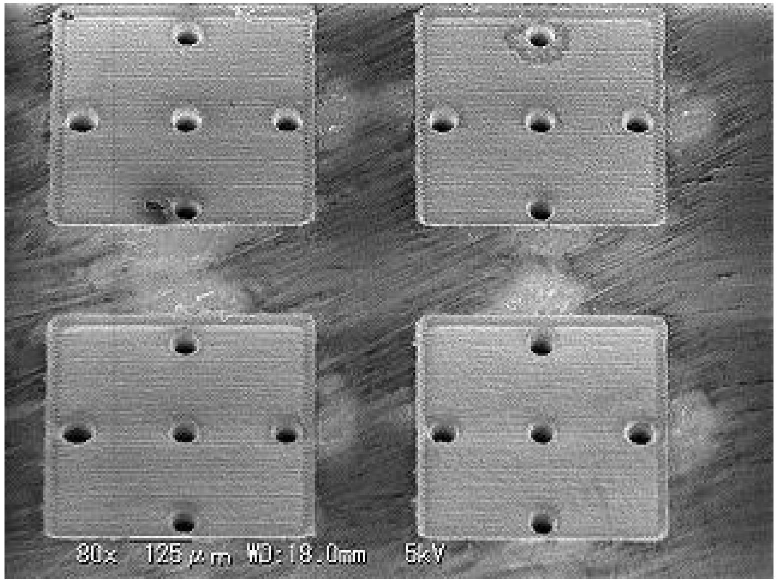



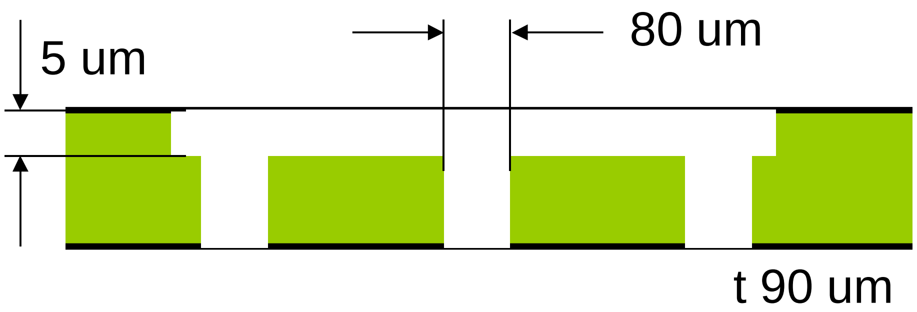



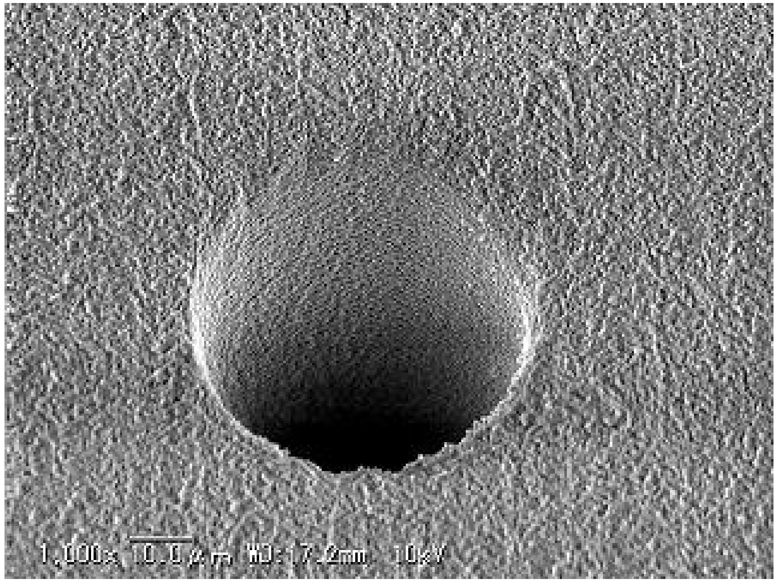
# Sapphire surface structuring





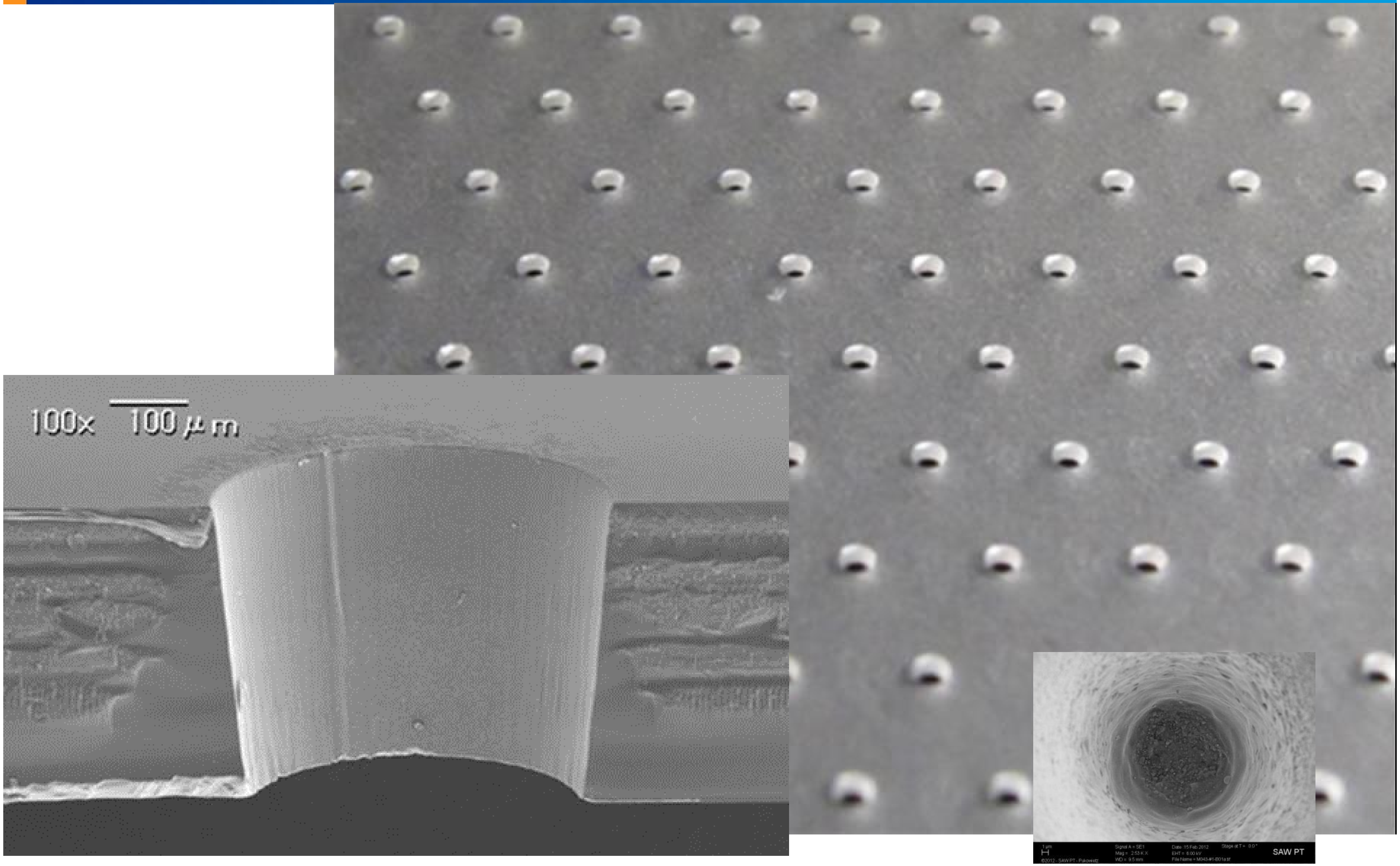



# Sapphire hole ( φ500 mm hole array )





# Via holes in product wafer



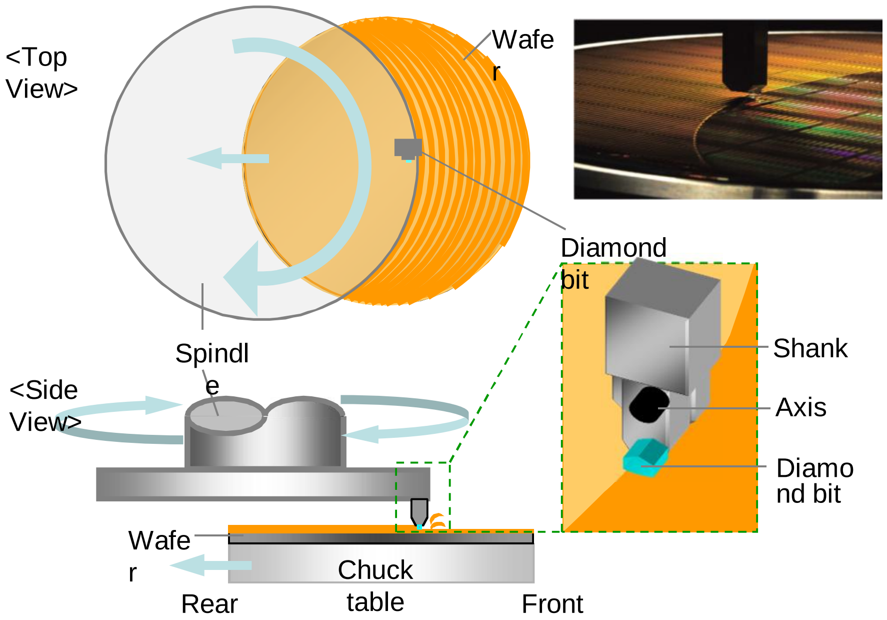
- Short pulse laser
  - IR, Green,UV
  - It is effective for a transparent material.

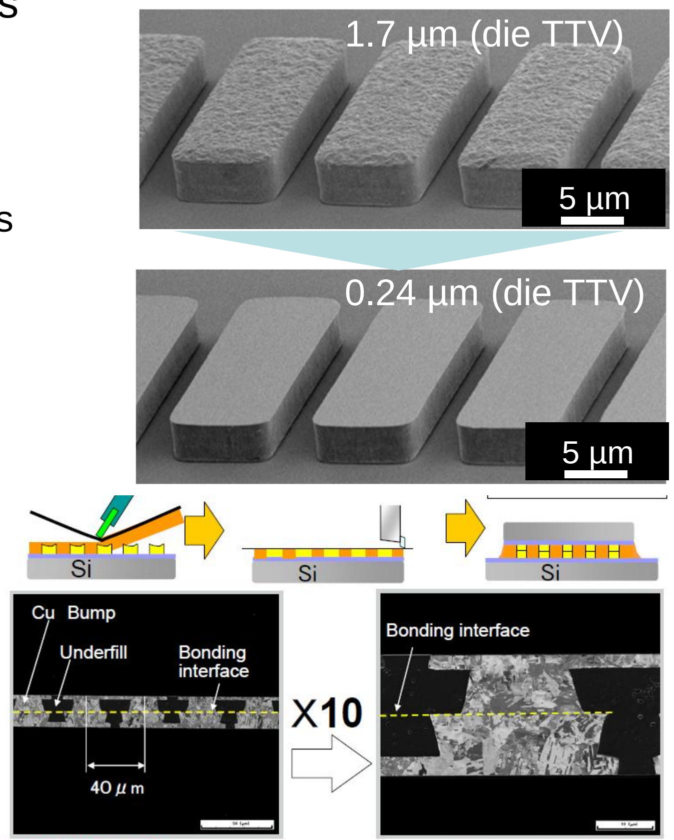
- Plasma detection system
  - Machine stops laser pulse automatically.
  - Detector watches every pulse.


# Surface Planarization



- Planarizing and smoothing composite workpieces such as aluminum, copper, nickel or soldering, and resin at once
  - Creep-feed method using a diamond bit
  - Usable for both wet and dry processes
  - Available for irregularly shaped workpieces other than wafers



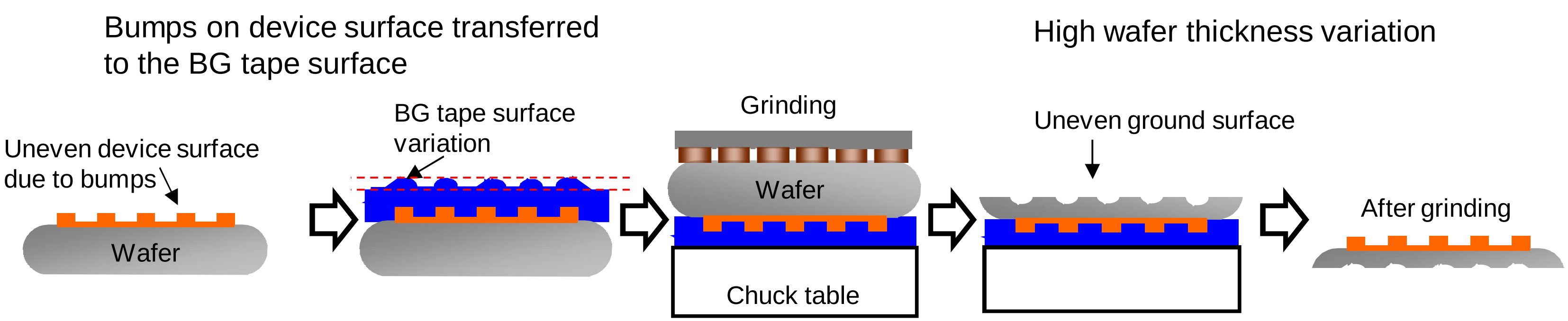

oad: 5g/Chip（No. of bump: 392）
'arameter: 280℃/30sec

Wafer: Provided by Fujitsu Laboratories Ltd.
Underfill: Provided by SEKISUI CHEMICAL CO., LTD.

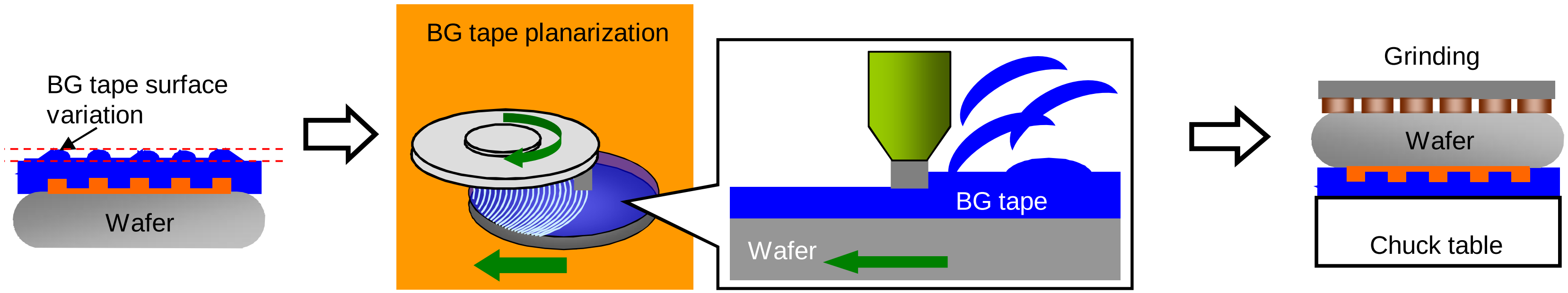
# BG Tape Planarization

- **Solution for bad TTV (total thickness value)**
  **-- Planarizing the uneven tape surface improves the TTV of the ground wafer**

## Conventional method




## New process with tape planarization




Unit: µm

| | Max. | Min. | TTV |
|---|---|---|---|
| Conventional method | 109.9 | 97.4 | 12.5 |
| With tape planarization | 100.6 | 98.8 | 1.8 |

**TTV improved by 10.7 µm!**

DISCO

Kiru・Kezuru・Migaku Technologies