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
Conventional Process

- Back Grinding Tape Laminating
- Back Grinding
- Stress relief
- Dicing Tape Mounting
- Back Grinding Tape Peeling
- Full Cut Dicing

DBG Process

- Half Cut Dicing
- Back Grinding Tape Laminating
- Back Grinding
- Stress relief
- Dicing Tape Mounting
- Back Grinding Tape Peeling

Die separation by back grinding

75 µm chip by single cut

3DICE 2stack B2F
SiC Grinding by GS08 and Dry Polishing

- Roughness: much finer than commonly used wheel for SiC

<table>
<thead>
<tr>
<th></th>
<th>SD1000-V462</th>
<th>GS08-SE0126 (#3000)</th>
<th>GS08-SE0135</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ra: 0.026 μm</td>
<td>Ra: 0.011 μm</td>
<td>Ra: 0.001 μm</td>
<td></td>
</tr>
<tr>
<td>Ry: 0.296 μm</td>
<td>Ry: 0.115 μm</td>
<td>Ry: 0.009 μm</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Grinding by #3000</th>
<th>Special DP08</th>
</tr>
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<tbody>
<tr>
<td>Ra: 0.009 μm</td>
<td>Ra: 0.001 μm</td>
<td></td>
</tr>
<tr>
<td>Ry: 0.063 μm</td>
<td>Ry: 0.010 μm</td>
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There are two thinning methods in fixing sapphire wafers.

<table>
<thead>
<tr>
<th>Method</th>
<th>Fixing on Substrate</th>
<th>Fixing on Ring Frame</th>
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<tbody>
<tr>
<td>Adhesive</td>
<td>Wax</td>
<td>Tape</td>
</tr>
<tr>
<td>How it looks like</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tools</td>
<td>DFG8830</td>
<td>DGP8761 (Frame grinding spec)</td>
</tr>
</tbody>
</table>
| Positive | • High fixing adhesive  
• Stable wafer edge in thinning  
• Rigid substrate       | • Automated process  
• No chemical cleaning necessary (cleaned by water)  
• No tape re-mounting (less process steps) |
| Negative  | • No automated process  
• Wafer cleaning process after detached.  
• Manual handling of Thinned wafer in cleaning  
• Mounting on dicing frame | • Rather weak in fixing  
• 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

Difficult workpiece examples
- Sapphire
- SiC
- Al₂O₃TiC (Altic)

Diagram of securing the tape frame

*Height of the chuck table

*The inner and outer circumference heights of the chuck table are aligned by self-grinding, therefore the outer circumference of the chuck table will be the chuck table height.
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<td>Wax</td>
<td>Tape</td>
</tr>
<tr>
<td>How it looks like</td>
<td>6 inch Sapphire wafer</td>
<td>8” Ring frame (296 mm OD)</td>
</tr>
<tr>
<td>Tools</td>
<td>DFG8830</td>
<td>DGP8761 (Frame grinding spec)</td>
</tr>
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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 S i C wafer process example

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

### Grinding amt (µm)

<table>
<thead>
<tr>
<th></th>
<th>Z1 #3000*</th>
<th>Z2 #3000*</th>
<th>Z3 #3000*</th>
<th>Z4 Fine mesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding amt (µm)</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>10</td>
</tr>
<tr>
<td>Finish Thickness</td>
<td>410</td>
<td>260</td>
<td>110</td>
<td>100</td>
</tr>
<tr>
<td>UPH</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Equivalent to #3000

**Wheel removal amount comparison**

- 2-axis
  - Z1 abrasive amount: 150 µm
  - Z2 abrasive amount: 450 µm
- 4-axis
  - Z1 abrasive amount: 150 µm
  - Z2 abrasive amount: 150 µm
  - Z3 abrasive amount: 10 µm
  - Z4 abrasive amount: 10 µm

Ex) 560 µm → 100 µm finish

Z1, Z2, Z3 : #3000

Z4 : Fine mesh
Sapphire Device Maker thinning

Cost & UPH : DFG8830

Grinding sample

- Z4 wheel: “#1400” (or “High-mesh”)

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

<table>
<thead>
<tr>
<th>Wafer size</th>
<th>Original thickness</th>
<th>Target thickness</th>
<th>Finish wheel</th>
<th>**UPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Φ 4 inch</td>
<td>900um</td>
<td>100um</td>
<td>#1400</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[High-mesh]</td>
<td>[18.5]</td>
</tr>
<tr>
<td>Φ 6 inch</td>
<td>1300um</td>
<td>140um</td>
<td>#1400</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[High-mesh]</td>
<td>[12.5]</td>
</tr>
</tbody>
</table>

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

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

**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

- 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

TAIKO Grinding

Less warpage and higher wafer strength
Picture: φ300 mm, 50 μm
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

<table>
<thead>
<tr>
<th>Features</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing quality</td>
<td>Fair</td>
</tr>
<tr>
<td>Feed speed</td>
<td>2 mm/sec</td>
</tr>
<tr>
<td>CoO</td>
<td>Very good</td>
</tr>
<tr>
<td>Usage</td>
<td>R&amp;D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blade Dicing</th>
<th>Laser Dicing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>ZP07</td>
</tr>
<tr>
<td>U09 (Ultrasonic wave processing)</td>
<td>Ablation</td>
</tr>
<tr>
<td>SD</td>
<td></td>
</tr>
</tbody>
</table>

| 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 |
| CoO | Very good | Good | Super good | Good | Fair |
| Usage | R&D | High volume production | (Under development) | R&D |

Cost for introduction and production capability

Expensive

Costs for introduction

Inexpensive

Low → High
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

<table>
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<tr>
<th>Difference in workpiece backside chipping</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Z</strong></td>
</tr>
<tr>
<td><strong>ZP07</strong></td>
</tr>
<tr>
<td><img src="image1.png" alt="Image of Z workpiece backside chipping" /></td>
</tr>
<tr>
<td>200 µm</td>
</tr>
</tbody>
</table>

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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

- U09 blade
- Ultrasonic wave oscillator
- Non-contact power feeding unit
- Normal spindle
- Dedicated mount
- Vibration direction

Processing point

- Abrasive grain
- Workpiece feeding direction
Ultrasonic Wave Dicing: High Throughput

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

Backside chipping

<table>
<thead>
<tr>
<th>Blade</th>
<th>2 mm/sec</th>
<th>5 mm/sec</th>
<th>10 mm/sec</th>
<th>20 mm/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td></td>
<td></td>
<td></td>
<td>Blade breakage</td>
</tr>
<tr>
<td>ZP07</td>
<td></td>
<td></td>
<td>Blade breakage</td>
<td></td>
</tr>
<tr>
<td>U09</td>
<td></td>
<td></td>
<td></td>
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# SiC Laser processing methods

<table>
<thead>
<tr>
<th>Processing method</th>
<th>Stealth Dicing (SD)</th>
<th>Ablation Process</th>
<th>Target wafer thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Formation of a modified layer by focusing SD laser inside</td>
<td>Scribing</td>
<td>50 to 400 µm</td>
</tr>
<tr>
<td></td>
<td>Grooving with short pulse laser</td>
<td>Full Cut</td>
<td>100 to 250 µm</td>
</tr>
<tr>
<td></td>
<td>Die separation by short pulse laser alone</td>
<td></td>
<td>150 µm or less</td>
</tr>
<tr>
<td>Advantage</td>
<td>High quality processing with almost zero kerf width</td>
<td>High speed processing and die separation of thick wafers</td>
<td>Die separation with high throughput of thin wafers</td>
</tr>
</tbody>
</table>

Target: up to 400 µm
## Current processing quality

<table>
<thead>
<tr>
<th>Wafer thickness [µm]</th>
<th>Feed speed [mm/s]</th>
<th>Number of passes</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>360</td>
<td>150</td>
<td>2 to 6</td>
<td>The number of passes can be changed depending on the required quality.</td>
</tr>
</tbody>
</table>

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

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

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

ø4” wafer
Index: 3.0 × 3.0 mm
GaN (Stealth dicing) t500um

7 passes
270 mm/s
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

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

<table>
<thead>
<tr>
<th>Wafer thickness [µm]</th>
<th>Feed speed [mm/s]</th>
<th>Number of passes</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>50</td>
<td>1</td>
<td>The cut depth can be changed depending on the ability to separate die.</td>
</tr>
</tbody>
</table>

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

- **Processing depth**: 103 µm
- **Kerf width**: 20.3 µm
- **No chipping**
  - ø4” wafer
  - Index: 3.0 × 3.0 mm
  - **UPH**: 17.4
Sapphire Stealth laser full cut  t=300um

50x 200μm WD:16.5mm 20kV 2012/12/04
Sapphire tilt shape  

$t=300\mu m$
Sapphire surface structuring

5 μm

80 μm

t 90 μm
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

1.7 µm (die TTV)

0.24 µm (die TTV)
**BG Tape Planarization**

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

**Conventional method**

- Bumps on device surface transferred to the BG tape surface
- High wafer thickness variation

**New process with tape planarization**

- BG tape surface variation

**TTV comparison**

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>Min</th>
<th>TTV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional method</td>
<td>109.9</td>
<td>97.4</td>
<td>12.5</td>
</tr>
<tr>
<td>With tape planarization</td>
<td>100.6</td>
<td>98.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

**TTV improved by 10.7 µm!**