MEMS - General and Plasma Dicing Process

Masaru Nonomura
Manager  Process Equipment Development Department, Panasonic Smart Factory Solutions

Bernhard Holz
Manager  Process Technology, ACCRETECH Europe GmbH
Agenda

• Dicing solutions for MEMS devices
• Mechanical Dicing
• Internally Focused LASER Dicing
• Plasma Dicing
• Conclusion
Dicing solutions for MEMS devices
Representative MEMS structures

Challenging process steps are “D/C tape mounting”, “Dicing” and “Die pick up” since they must not damage or contaminate the fragile MEMS structure.

In principle there are 3 different types of structures:

1. A) Without cavity
2. B) With breathable cavity
3. C) With non-breathable cavity
MEMS Dicing methods

1. Mechanical dicing (with protection tape)
   … is still used in the market due to lower investment cost. However, it is a complicated process causing low yield.

2. Internally Focused LASER Dicing
   … is widely used for MEMS but especially needed for “Microphone”, “Pressure sensor” and “Inkjet device” since those devices cannot be covered by a cap.

3. Plasma dicing
   … is just starting to get introduced to the MEMS market. It is the only way to minimize particle count towards “Zero” during dicing.
Mechanical Dicing
Mechanical dicing with protection tape

The protection tape on the wafer surface is required to protect fragile MEMS structures against water splash and silicon dust that is generated by dicing.
ACCRETECH’s mechanical dicing tools
SS / AD / PS series

<table>
<thead>
<tr>
<th>Model</th>
<th>SS10</th>
<th>SS20</th>
<th>SS30</th>
<th>AD20T</th>
<th>AD2000T</th>
<th>AD3000T</th>
<th>PS300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work size</td>
<td>6 inch</td>
<td>8 inch</td>
<td>12 inch</td>
<td>8 inch</td>
<td>8 inch</td>
<td>12 inch</td>
<td>12 inch</td>
</tr>
<tr>
<td>Spindle</td>
<td>Single</td>
<td>Single</td>
<td>Single</td>
<td>Twin</td>
<td>Twin</td>
<td>Twin</td>
<td>Twin</td>
</tr>
<tr>
<td>Loader</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Handler</td>
</tr>
</tbody>
</table>

http://www.accretech.jp
Internally Focused LASER Dicing
Internally Focused LASER Dicing

As MEMS devices contain a fragile structure, a dicing technology is required which applies only little stress. Furthermore it should ensure...

1) Completely Dry Dicing Process

2) Non-contact Type Dicing Process
Conventional Blade Dicing vs Internally Focused LASER Dicing

**Blade Dicing**
- Water
- Chipping (particles)
- Saw Dust
- Wide Kerf loss

**Internally Focused Laser Dicing**
- No water
- Laser
- No chipping
- Less particles
- No Kerf loss
- t=400µm
ACCRETECH’s LASER dicing tools

ML series

<table>
<thead>
<tr>
<th>Model</th>
<th>ML200EX</th>
<th>ML300EX FH</th>
<th>ML300EX WH</th>
<th>ML300EX FHWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work size</td>
<td>8 inch</td>
<td>12 inch</td>
<td>12 inch</td>
<td>12 inch</td>
</tr>
<tr>
<td>Loading port</td>
<td>2 (Dicing Cassette)</td>
<td>1 (Dicing Cassette)</td>
<td>2 (Wafer Carrier)</td>
<td>1 (Dicing Cassette)</td>
</tr>
<tr>
<td>Handling</td>
<td>Frame</td>
<td>Frame</td>
<td>Wafer</td>
<td>Frame and Wafer</td>
</tr>
</tbody>
</table>

1st LASER dicer released to the market in 2005
Plasma Dicing
IoT business growth and device evolution

### IoT devices growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of IoT devices (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>300</td>
</tr>
<tr>
<td>2017</td>
<td>500</td>
</tr>
<tr>
<td>2019</td>
<td>800</td>
</tr>
<tr>
<td>2021</td>
<td>1,200</td>
</tr>
<tr>
<td>2023</td>
<td>1,400</td>
</tr>
<tr>
<td>2025</td>
<td>1,600</td>
</tr>
<tr>
<td>2027</td>
<td>1,800</td>
</tr>
<tr>
<td>2029</td>
<td>2,000</td>
</tr>
</tbody>
</table>

**CAGR:** 12.1% from 2015 to 2030

**Source:** IHS Technology

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### Key devices

**MEMS sensors**
- Image sensors
- Integration (sensor/function integration)
- Miniaturization (CSPs)

**Communication devices/AP&BB/memory**
- Higher frequency
- Integration (e.g., BB+RF)
- Thinner designs

**CPU/GPU memory**
- Greater capacity, faster
- Integration (3DIC, etc.)

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### Business cycle with IoT application

- High-speed communication
- Cloud
- Big data
- Service provision
- High-speed processing
- Sensing
- 5G
- AI

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Demands for Dicing process

Trends of MEMS device.
✓ Low cost and High reliability
✓ High specification
✓ Down sizing (Light, Thin, small)
✓ Flexible design

Demands for Dicing process
✓ Higher throughput
✓ Damage free and stress free process
✓ Higher accuracy dicing
Introduction of new process “Plasma dicing”

Blade dicing

- Mechanical
- ✓ Damage
- ✓ Low Machine Cost

Plasma dicing

- Gas Etching
- ✓ Damage Free
- ✓ Need Mask Patterning

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Process flow with Laser and Plasma dicer

<table>
<thead>
<tr>
<th>Plasma Dicing Process</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mask patterning</strong></td>
<td><strong>Dicing</strong></td>
</tr>
<tr>
<td>Resist Coating</td>
<td>Laser patterning</td>
</tr>
<tr>
<td>Photo resist</td>
<td>Laser</td>
</tr>
<tr>
<td>ACCRETECH</td>
<td>AL300P</td>
</tr>
<tr>
<td>Panasonic APX300-DM</td>
<td>©2018 Panasonic Smart Factory Solutions Co., Ltd.</td>
</tr>
</tbody>
</table>
Process Flow

1. BG tape lamination
2. Back grinding
3. Dicing tape lamination
4. BG tape delamination
5. Coating
6. Laser patterning
7. Plasma dicing
8. Rinse

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High reliable damage-less process
<table>
<thead>
<tr>
<th></th>
<th>Blade dicing</th>
<th>Plasma dicing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device side</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>BG side</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>TEM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Device side</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>BG side</td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Plasma dicing is no chipping and no damage process

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Strong Chip

3 point bending test result

Mapping data

- blade dicing: Ave.357
- plasma dicing: Ave.1514

3 point bending

Higher bending strength with narrow distribution

[Note] Si wafer size: 8 inch
chip size: 5x15mm
Thickness: 150um

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Comparison of breaking mode

<table>
<thead>
<tr>
<th></th>
<th>Blade dicing (Cleavage mode)</th>
<th>Plasma dicing (Crushing mode)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braking mode</td>
<td>![Blade dicing image]</td>
<td>![Plasma dicing image]</td>
</tr>
<tr>
<td>Before chip strength test</td>
<td>![Before chip strength test]</td>
<td>![Before chip strength test]</td>
</tr>
<tr>
<td>Chipping due to dicing damage</td>
<td>![Chipping due to dicing damage]</td>
<td>![No chipping]</td>
</tr>
<tr>
<td>After chip strength test</td>
<td>![After chip strength test]</td>
<td>![After chip strength test]</td>
</tr>
<tr>
<td>Start breaking from chipping</td>
<td>![Start breaking from chipping]</td>
<td>![Original destruction mode of silicon]</td>
</tr>
</tbody>
</table>

Plasma dicing increases chip strength to original silicon strength
High accuracy dicing
High accuracy dicing

Blade dicing

Wide chip margin

Device area

60μm

20μm

Plasma dicing

Minimize chip margin

Device area

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High yield process
More chips by street reduction

**Blade dicing**

<table>
<thead>
<tr>
<th>Num. of chips from one wafer</th>
<th>Blade</th>
<th>Plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street width</td>
<td>60μm</td>
<td>20μm</td>
</tr>
<tr>
<td>Num. of chips</td>
<td>27,500</td>
<td>29,800</td>
</tr>
</tbody>
</table>

(φ8inch, □1mm)

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Narrower dicing line

Die size: □1mm
Narrow(<5um) Street plasma dicing

- narrow street & high speed dicing: width within 5μm

Si etching rate = 10μm/min

For small chip, plasma dicing can achieve low COO
Zigzag layout

Yield improvement by zigzag layout
Flexible design for MEMS
Optimum shape
Summary

Panasonic plasma can help high quality and low cost MEMS device production.

✓ High reliability
  Damage-less and stress-free process
✓ Optimum shape
  Flexible mask design by laser patterning
✓ High accuracy dicing
  Chipping-free and Damage-free process
✓ Maximum chip yield
  Minimize dicing street and Zigzag layout
Plasma Dicing Demo Center in PSFS, Osaka, Japan

✓ Total process can be test with entire plasma dicing method.
✓ Collaborative researching on plasma dicing with our partner companies.

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Conclusion
### Conclusion

It will be required higher reliability process on the automotive market. Plasma dicing is able to meet this requirement.

<table>
<thead>
<tr>
<th>Dicing method and tools</th>
<th>Mechanical</th>
<th>Internally focused LASER</th>
<th>Plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diamond Blade</td>
<td>NIR pulse LASER</td>
<td>LASER patterning and Plasma etching</td>
</tr>
<tr>
<td>Surface protection</td>
<td>Required protection film</td>
<td>Not Required</td>
<td>Required mask coating</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Required to remove protection film</td>
<td>Not Required</td>
<td>Required to remove mask</td>
</tr>
<tr>
<td>Damage</td>
<td>Risk for mounting on and peeling off the tape</td>
<td>No damage</td>
<td>No damage</td>
</tr>
<tr>
<td>Particle</td>
<td>A large amount of particle</td>
<td>Slight particle</td>
<td>No particle</td>
</tr>
<tr>
<td>Die strength</td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>Variant die (Hexagon, etc.)</td>
<td>Impossible</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td>CoC</td>
<td>Low</td>
<td>Low</td>
<td>(Depend on wafer thickness and die size)</td>
</tr>
<tr>
<td>Reliability</td>
<td>Low</td>
<td>Middle</td>
<td>High</td>
</tr>
<tr>
<td>Overall</td>
<td>There are a lot of risk on this process. It will be able to apply only for some specific MEMS.</td>
<td>It will be able to apply for most of the MEMS devices. However it is NOT perfect solution for particle free.</td>
<td>It will be able to apply for most of the MEMS. Moreover it is perfect solution to avoid contamination.</td>
</tr>
</tbody>
</table>
Thank you for your attention.