Structuring and bonding of glass-wafers

Dr. Anke Sanz-Velasco
• **IMT**
  - Why glass?
  - Components for life science
  - Good bond – requirements and evaluation
  - Wafer bonding
    1. Fusion bonding
    2. UV-adhesive bonding
  - Customer-specific development of UV-adhesive bonding
  - Laser dicing
**IMT Masken und Teilungen AG - Keydata**

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>Dr. Rüst AG, Stäfa in 1959</td>
</tr>
<tr>
<td>Ownership</td>
<td>HEIDENHAIN Group since 1994</td>
</tr>
<tr>
<td>Employees</td>
<td>107</td>
</tr>
<tr>
<td>Revenue 2016</td>
<td>CHF 25 Mio.</td>
</tr>
<tr>
<td>Investment ratio</td>
<td>15% of total revenue</td>
</tr>
<tr>
<td>Cleanroom</td>
<td>1500 m²</td>
</tr>
<tr>
<td>Substrates</td>
<td>70,000 / year</td>
</tr>
<tr>
<td>Components</td>
<td>1.4 Mio. pcs / year</td>
</tr>
<tr>
<td></td>
<td>Traceable to METAS, ISO 9001:2000 and NIST certification</td>
</tr>
</tbody>
</table>

**Consumables in glass for Life Science applications**
Services for Life Science industry

Development and large scale manufacture of cost effective glass consumables

- Complete assembled flow cells
- Nano- and micro-patterns on glass
- Nano-wells and channels in glass
- Nanopillars in glass
- Structured electrodes on glass
- Planar or structured Waveguides and phase gratings to guide and couple light
- Structured polymers (photoresists)
- Covalent bond chemistry
- Through-holes
- In-house master manufacture
- Bonding of glass substrates
Outline

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  1. Fusion bonding
  2. UV-adhesive bonding
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## Why glass?

<table>
<thead>
<tr>
<th>Excellent physical properties</th>
<th>Other benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mechanical:</strong></td>
<td></td>
</tr>
<tr>
<td>Homogeneous and isotropic</td>
<td>Cost efficient</td>
</tr>
<tr>
<td>Good mechanical stability</td>
<td>Good process ability (polishing, grinding, dicing, breaking, etc.)</td>
</tr>
<tr>
<td>Light weight (density = 2.5 g/cm³)</td>
<td>Available in different forms (flat glass, tubes, etc.)</td>
</tr>
<tr>
<td></td>
<td>Many variants</td>
</tr>
<tr>
<td></td>
<td>(float-, silicate-, flint-glass, glass ceramics, quartz etc.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Optical:</th>
<th>MEMpax® Borosilicate glass wafers Schott</th>
</tr>
</thead>
<tbody>
<tr>
<td>High transparency (visible to IR)</td>
<td></td>
</tr>
<tr>
<td>Low fluorescence</td>
<td></td>
</tr>
</tbody>
</table>

| Electrical:                  |                                           |
|------------------------------|                                           |
| Low thermal expansion        |                                           |
| Electrical isolator         |                                           |

| Chemical:                    |                                           |
|------------------------------|                                           |
| High chemical resistance    |                                           |
| Chemically inert            |                                           |
Outline

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Components for life science

Etched channels
Micro- and nanostructures
Holes and via holes
Components for life science - automated process line for Ø 200 mm

Cleaning

Coating

Lithography: resist coating

Lithography: exposure

Lithography: developing, etching and cleaning

Prozessablauf
Components for life science - microchannels and -wells

Microchannels and -wells in glass using wet etching (HF)

Advantages:
- Cost effective
- Homogeneous etching, i.e. surface roughness <50 nm
- High degree of freedom in the pattern design

Limitations:
- Vertical walls and high aspect ratios not possible
- Isotropic process, i.e. the channels are always broader than deep and wider than the structures in the etching barrier (Masking).

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Glass micro-reactor

Smallest feature size 10µm
Components for life science - glass etching - HF spray

Etching of microstructures in glass 16 x Ø 200mm wafer / batch with excellent homogeneity (± 1% within the batch)

Complete processing dry-in – dry-out

Use of different
- Chemistries and concentration (HF, HNO3, HCl,...) and
- Glass types (B270, D263, Borofloat, Mempax)
Components for life science - glass etching - HF spray

Reaction
\[ \text{SiO}_2 + 6 \text{HF} \rightleftharpoons \text{H}_2\text{SiF}_6 + 2\text{H}_2\text{O} \]

Spray acid process
- Chemistry (temperature variable)
- Circulation (defined flow) guarantees homogeneity

Masking
- Stressfree \(\leftrightarrow\) Layer thickness
- Pinholefree \(\leftrightarrow\) Layer composition
- Free from scratches \(\leftrightarrow\) Cleanliness
- Good adhesion \(\leftrightarrow\) Chemical binding, surface

Etch quality
- Adequate etch rate
- No crystallites \(\rightarrow\) HF-concentration & mixing ratio
- Surface roughness
Components for life science - glass etching - HF spray

(1-5) Microfluidic structures

(6) Overetched grid
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Requirements for a good bond

Requirements

- Contaminant free surfaces
- Surface roughness
- Wafer bow
- Surface conditioning
- Total thickness variation
- Atmosphere; e.g. pressure, temperature, humidity

Evaluation

- Voids
- Bond strength
- Leak tightness
- Adhesive profile
- Uniform bond interface
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Wafer bonding

ISO class 4
1. Fusion bonding:

![Diagram of wafer bonding with labeled components: Glass, Laminate, Metal, Adhesive]
1. **Fusion bonding:**

   ![Fusion bonding diagram]

2. **UV-adhesive bonding:**

   ![UV-adhesive bonding diagram]
Wafer bonding - Fusion bonding

Cleaning ➔ Alignment ➔ Bonding ➔ Annealing

@300°C
@500°C

Process flow
Advantages

- Room-temperature processes allowing for encapsulation of bio-materials
- Compatible with a wide range of materials
- Insensitive to surface roughness
- Ultra-thin selective adhesive transfer technology with excellent uniformity over large areas
Wafer bonding - **UV-adhesive bonding**

**Process flow**

1. Cleaning
2. Coating
3. Adhesive transfer
4. Alignment
5. Bonding
6. Curing
Wafer bonding - UV-adhesive bonding

Spin on adhesive on Kapton

Spin on adhesive onto foil
Wafer bonding - UV-adhesive bonding

Spin on adhesive onto foil

Adhesive transfer
Wafer bonding - **UV-adhesive bonding**

Spin on adhesive onto foil

Adhesive transfer

Wafer with adhesive
Wafer bonding - **UV-adhesive bonding**

- **Spin on adhesive onto foil**
- **Adhesive transfer**
- **Wafer with adhesive**
- **Bonded wafer**
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Customer-specific development of UV-adhesive bonding

Requirements on UV-adhesive

- Non fluorescent
- Moisture resistant
- Chemical inert
- Mechanical stable

Adhesive 1

- UV-hardening urethan acryl adhesive

Adhesive 2

- UV-/ thermal hardening epoxy adhesive
Customer-specific development of UV-adhesive bonding

Adhesive

Thickness adhesive 300 nm
Customer-specific development of UV-adhesive bonding

Aim: Adhesive layer thickness 3.5 µm
     Variation target value ±1.0 µm
     Wafer uniformity ±1.5 µm
Customer-specific development of UV-adhesive bonding

Cavity

Small distance between cavities

Wide distance between cavities

Adehsive-1.1
4500 rpm
0 N

No adhesive

Adehsive-1.2
4500 rpm
0 N

No adhesive

Adehsive-1.3
4500 rpm
0 N

No adhesive

Adehsive-1.4
4000 rpm
0 N

No adhesive

Adehsive-1.5
4000 rpm
0 N

No adhesive

Adehsive-1.6
4000 rpm
2 kN

No adhesive

Structuring and bonding of glass-wafer
Customer-specific development of UV-adhesive bonding

![Diagram of cavities and distances between cavities]

- **Cavity**
- **Small distance between cavities**
- **Wide distance between cavities**

**Adhesive-1.4**
- 4000 rpm
- 0 N
- ca. 1.7 µm

**Adhesive-1.5**
- 4000 rpm
- 0 N
- ca. 0.9 µm

**Adhesive-1.6**
- 4000 rpm
- 2 kN
- ca. 0.8 µm

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**Customer-specific development of UV-adhesive bonding**

**Cavity**
- Small distance between cavities
- Wide distance between cavities

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**Chemnitzer Seminar**

Structuring and bonding of glass-wafer

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**SYSTEM INTEGRATION TECHNOLOGIES**

13-14.06.2017
Customer-specific development of UV-adhesive bonding

**Adhesive 1**: D263; 4500 rpm; 0 kN

Adhesive layer thickness as function of distance to cavity
Customer-specific development of UV-adhesive bonding

Adhesive 2 blends into cavities
Customer-specific development of UV-adhesive bonding

Adhesive 2: D263; 4500 rpm; 0 kN

Adhesive layer thickness as function of distance to cavity
Customer-specific development of UV-adhesive bonding

Parameter

Pre-treatment
• Wafer
• Foil

Adhesive transfer
• Volumen adhesive
• Acceleration speed
• Revolution speed

Adhesive transfer
• Contact pressure
• Speed
• Mechanical adjustments

Bonden
• Mechanical adjustments
• Atmosphere
• Contact pressure

Curing
• Intensity
• Duration
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Laser dicing

- High dicing accuracy
- Minimal chipping
- No material waste
- Cut through metallic & DE coatings
Thank you for your attention!

IMT is a member of the Microfluidics Consortium.