INKJET PRINTING FOR SEMICONDUCTOR PACKAGING

IMAPS, Device Packaging Conference
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WHY SHOULD WE USE INKJET PRINTING?
WHY SHOULD WE USE INKJET PRINTING

+ What is inkjet printing?

+ What are the advantages of inkjet printing?

+ What materials can be inkjet printed?

+ Which application can be addressed with inkjet printing?
WHAT IS INKJET PRINTING?

Sense of scale
4 pL droplet = ~20 µm diameter
30 pL droplet = ~40 µm diameter
WHAT IS INKJET PRINTING?

Sense of scale
Typical inkjet resolution: ~1000dpi → ~25µm per pixel
Typical feature sizes:
4pl droplet on surface → ~50µm
30pl droplet on surface → ~100µm
WHAT IS INKJET PRINTING?

Direct patterning
- Functional materials

Homogeneous layers
- Passivation coatings
- Encapsulation

Resist
- Solder resist
- Etching
- Plating

Sense of scale: Feature sizes:
Positive features → >50µm*
Negative features → >20µm*  
* Highly depends on interaction of ink with substrate
WHAT IS INKJET PRINTING?

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Fujifilm Dimatix</th>
<th>Konica Minolta</th>
<th>Canon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series</td>
<td>Q-Class</td>
<td>Samba</td>
<td>KM1024i</td>
</tr>
<tr>
<td>Nozzles</td>
<td>256</td>
<td>2048</td>
<td>1024</td>
</tr>
<tr>
<td>Nozzle density</td>
<td>100</td>
<td>1200</td>
<td>360</td>
</tr>
<tr>
<td>Maximum frequency</td>
<td>50</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Native drop volume</td>
<td>10 – 80</td>
<td>2.5</td>
<td>6 – 30</td>
</tr>
<tr>
<td>Maximum temperature</td>
<td>90</td>
<td>60</td>
<td>55</td>
</tr>
</tbody>
</table>

NOTE: Other printheads may also be integrated

Sense of scale
Typical print time for 8 or 12 inch wafer → ~ 1 minute*
* Highly depending on specific process requirements
WHAT ARE THE ADVANTAGES OF INKJET PRINTING?

Traditional process flow

- Pre-treat
- Coat
- Produce artwork
- Expose
- Develop
- Cure

Inkjet printing process flow

- Pre-treat
- Print
- Cure

- Eliminate artwork production, exposure and development

- Reducing handling, floor space, maintenance and cleaning
- Efficient material usage
- Green process, less chemistry and less waste disposal
- No more need for mask production, storage and logistics
WHAT ARE THE ADVANTAGES OF INKJET PRINTING?

Digital patterning:
- Individual scaling per product → to correct for deformation in upstream processes
- Different image per product → with information from upstream processes
- Quick turnaround, e.g. high mix
- Variable layer thickness

Direct patterning:
- No need for removal of materials

Non-contact deposition:
- Printing on delicate surfaces
- Compatible with non-flat topography
**WHAT MATERIALS CAN BE INKJET PRINTED?**

<table>
<thead>
<tr>
<th><strong>Ink types</strong></th>
<th>Polymers based on acrylate, epoxy and polyimide 100% solid or solvent based Nanoparticle dispersion Phase change (hotmelt)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Viscosity</strong>*</td>
<td>2 – 20 cPoise (mPa s)</td>
</tr>
<tr>
<td><strong>Surface tension</strong></td>
<td>24 – 36 Dyne/cm (mN/m)</td>
</tr>
<tr>
<td><strong>Post treatments</strong></td>
<td>Temperature curing UV curing Sintering (photonic, laser, heating)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Temporary materials</strong></th>
<th><strong>Permanent materials</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Resists</td>
<td>Dielectric</td>
</tr>
<tr>
<td>Hotmelt</td>
<td>Polyimide</td>
</tr>
<tr>
<td>UV-curable resists</td>
<td>SU-8</td>
</tr>
<tr>
<td>Photo resist</td>
<td>Solder Mask</td>
</tr>
</tbody>
</table>

*Sense of scale, viscosities:
- Water: 1cP
- Olive oil: 80cP
- AZ P4620: 563cP

00980
INKJET PRINTING OF RESISTS
INKJET PRINTABLE PHOTORESIST

Optical Centering (Camera)  Plasma  Spin Coating  Softbake  Coolplate  EBR  Exposure  Develop  Hardbake  Coolplate

~85% of photoresist wasted
INKJET PRINTABLE PHOTORESIST

Inkjet printing deposits material only where it is needed → no wasted photoresist
INKJET PRINTABLE PHOTORESIST

+ AZ P4000 series resist adjusted for inkjet printing
+ Printed with 2.5mm edge exclusion
+ Layer thickness (after softbake):
  ▪ Average: 10.3µm
  ▪ StDev: 0.1µm (5mm edge exclusion)
Why not skip the whole exposure & development step → directly patterned photoresist for feature size >100µm
INKJET PRINTABLE RESISTS

<table>
<thead>
<tr>
<th>Ink types</th>
<th>Hotmelt, UV curable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum feature size*</td>
<td>&gt; 50/20 µm L/S</td>
</tr>
<tr>
<td>Layer thickness*</td>
<td>10 – 100 µm</td>
</tr>
<tr>
<td>Applications</td>
<td>Wet-chemical etching and plating</td>
</tr>
<tr>
<td>Properties</td>
<td>Acid resistant</td>
</tr>
</tbody>
</table>

*Actual performance depending on ink, process and substrate

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**Print Process**

- UV-curable resist on GaAs
- Hotmelt on Cu
- Hotmelt on Si

**Result**

- >20 µm
- >50 µm

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INKJET PRINTABLE RESISTS

- Typical masking thickness of 1 layer: ~40µm → multiple layers created thicker masks
- Edge angle: ~80°
Cu plated trace on Cu seed layer with inkjet printed plating resist
Courtesy CSEM, Switzerland
INKJET PRINTING OF DIELECTRICS
# Dielectric Inks

<table>
<thead>
<tr>
<th>Ink types</th>
<th>SU-8, Polyimide, Acrylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum feature size*</td>
<td>50 - 150 µm</td>
</tr>
<tr>
<td>Layer thickness*</td>
<td>1 - 100 µm</td>
</tr>
<tr>
<td>Applications</td>
<td>Isolation, protection, filling, stress buffer, encapsulation, solder resist</td>
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</table>

*Actual performance depending on ink, process and substrate

Stress buffer layers directly printed at wafer level

Courtesy Texas Instruments
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<tbody>
<tr>
<td>Minimum feature size*</td>
<td>50 - 150 µm</td>
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<tr>
<td>Layer thickness*</td>
<td>1 to &gt;500 µm</td>
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<tr>
<td>Applications</td>
<td>Isolation, protection, filling, stress buffer, encapsulation, solder resist</td>
</tr>
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</table>

*Actual performance depending on ink, process and substrate

3D printed dielectric dams (150µm dams, 300µm height)

3D printed dielectric dams (100µm dams, 100µm height)
SOLDER MASK ON PCB

<table>
<thead>
<tr>
<th>Ink types</th>
<th>Solder mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum feature size*</td>
<td>&gt;75 µm line/space</td>
</tr>
<tr>
<td>Layer thickness*</td>
<td>&gt;5 µm</td>
</tr>
<tr>
<td>Applications</td>
<td>Isolation, protection, filling, stress buffer, encapsulation, solder resist</td>
</tr>
</tbody>
</table>

5 mil or ~125µm
SOLDER MASK ON PCB

No soldermask

Thick on Cu (~35 µm)

Thin on FR4

Medium thickness on copper
SOLDER MASK ON QFN

+ Solder mask printing on Copper leadframe
WHY USE INKJET PRINTING?
**WHY USE INKJET PRINTING?**

**What is inkjet printing?**
- Printing millions of small droplets to form a digital pattern
- Creating features of >50µm
- Typical print time ~1 min for 8” or 12” wafer

**What are the advantages of inkjet printing?**
- Direct patterning of functional layers
- Reducing handling, floor space, maintenance and cleaning
- Efficient material usage
- Green process, less chemistry and less waste disposal
- No more need for mask production, storage and logistics
- Individual scaling per product
- Variable layer thickness
- Compatible with non-flat topography
- Printing on delicate surfaces

**Which materials can be inkjet printed?**
- Resists: photoresist, inkjet masks
- Dielectrics: SU-8, polyimide, solder mask

**Which applications can be addressed with inkjet printing?**
- Full surface photoresist to save resist cost
- Direct patterned resists
- Stress buffer
- Dams
- Solder mask as protection
WHICH INKJET EQUIPMENT CAN WE USE?

- LP50 R&D inkjet printer
- JETxM inkjet printer (24” x 30”)
- ACS with JETxS inkjet module (8” or 12”)

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Thank you!