Material technology enhances the density and the productivity of the package

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Outline

1. Materials for high density packaging
2. Bonding Force Leveling (BFL) Film
3. Molded reflow process with NCF & EMC
4. Bump Stabbing process
5. RDL-first FO-PLP TV and “JOINT”
6. Summary
Packaging material product line up of Hitachi Chemical

- **Flip Chip BGA**
- **Stacked CSP**
- **Wafer Level CSP**
- **FOWLP**
- **2.5D PKG**
- **3D PKG**

- Buffer Coatings/Redistribution Materials
- CMP Slurry
- Die Attach Film
- Dielectric Material/Build UP, SAP Prepreg
- Dry Film Resist
- Release Film
- Substrate
- Solder Resist
- Temporary Bonding Film
- Solid/Liquid EMC, Embedded Sheet
- Thermally Conductive Film
- Temporary Bonding Film
- Underfill
Material can contribute to the performance of the high density package

**Thermal Interface material**
- High thermal conductive: 40 W/mK

**Underfill material**
- CUF: Small gap filling: 25 μm
- NCF: Thin die: <50 μm

**EMC**
- High thermal conductive: 6 W/mK
- Low loss: Df=0.005@60GHz

**Organic laminate**
- Low CTE: 0.8 ppm/°C
- Low Loss: Df=0.0035@10GHz

**Solder resist**
- High Tg: >200°C
- Low CTE: <20 ppm/°C

**Dry film resist**
- Resolution: L/S=2/2 μm

Can material do other contributions?
Issues of high density interconnecting

Typical die configurations of high density packages

Side by side (2.5D)

- Fine pitch
- Many bumps

Die stack with TSV (3D)

Precise alignment and small bump interconnection.
Thermal compression bonding (TCB) is usually used.

Low productivity!

Can material enhance the productivity?
Function of Packaging Solution Center (PSC) of HC

- Package TV design
- Evaluation of material property
- PSC for assembly
- Evaluation of package reliability
- Modeling
- Package (RDL) wiring
- Assembly of Advanced package
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Improvement of productivity in TCB process

◆ Conventional TCB process

Pre-bonding

Main bonding (die by die)

• The die by die sequential process step

◆ Gang-bonding process

Pre-bonding

Main bonding (gang-bonding)

• Multi die soldering on the substrate with single large head

Gang-bonding process can significantly enhance the productivity
Issues of gang bonding on TCB

• Unparalleled head

• Unevenness of the die height (due to bump height, pad thickness, and thickness unevenness of substrate surface)

Die shift and the shortage of bonding force may happen at the gang-bonding
Characteristics of the BFL film

Structure of the BFL film
- Heat-resistant layer
- Thermosetting resin layer
- Heat-resistant layer

DSC chart of the BFL film

Thermosetting resin layer of BFL film cures faster than the resin of NCF to compensate the height difference among the dies before multi dies gang bonding.
BFL film compensates the deviation

BFL can enhance the productivity of TCB process

Die placement

Without BFL film

With BFL film

Gang bonding

Interconnection error due to gap deviation

BFL can compensate the gap deviation
High productivity gang bonding!
**Test vehicle specification**

| Die                  | 7.3 mm × 7.3 mm, 100 μm<sup>1</sup>  
| Peripheral bump : 80μm pitch  
| Full array bump : 300μm pitch  
| Bump height : Cu Pillar (30 μm<sup>1</sup>)  
| +SnAg Solder (15 μm<sup>1</sup>) |
| Substrate           | Top layer Cu thickness: 15 μm  
| Total thickness: 0.36 mm |
| NCF                 | Thickness: 40 μm |

**Evaluation**

- Daisy chain (all dies)
- Die shift (A-E dies)
- Void in NCF

**Condition**

- 80 °C/50 N/3 s
- Gang bonding by HTB-MM (Alpha Design Co., Ltd.)  
  Condition: 300 °C/750 N/15 s
### The results of gang-bonding with BFL

<table>
<thead>
<tr>
<th>Item</th>
<th>No film</th>
<th>Teflon</th>
<th>BFL film</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daisy chain test (Pass/Total)</td>
<td>8/15</td>
<td>14/15</td>
<td>15/15</td>
</tr>
<tr>
<td>Die shift after pre-bonding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave. die shift</td>
<td>30 μm</td>
<td>27 μm</td>
<td>5 μm</td>
</tr>
<tr>
<td>Void in NCF by C-SAM observation</td>
<td>NG</td>
<td>OK</td>
<td>OK</td>
</tr>
</tbody>
</table>

The BFL film performed well at 15-die gang bonding.
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“Molded reflow” process

Pre-bonding

NCF laminated die

Wafer

Bonding tool

Molding

Solder joint formation

Reflow

Only placement! No TCB!

Die

NCF

Bonding tool A

Only placement! No TCB!
# Die specification of TV

<table>
<thead>
<tr>
<th></th>
<th>Top die</th>
<th>Bottom die</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.3 mm x 7.3 mm, 100 μm(^t)</td>
<td>10 mm x 10 mm, 100 μm(^t)</td>
</tr>
<tr>
<td></td>
<td>Passivation: SiN</td>
<td>Passivation: SiN</td>
</tr>
<tr>
<td></td>
<td>Peripheral bump: 80 μm pitch, 648 pin</td>
<td>Pad: Ni/Au plating</td>
</tr>
<tr>
<td></td>
<td>Full array bump: 300 μm pitch, 400 pin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bump height:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cu Pillar (30 μm(^t)) + Sn/Ag Solder (15 μm(^t))</td>
<td></td>
</tr>
</tbody>
</table>

**Peripheral bump**

**Full array bump**

**Full array pad**
CoC assembly by molded reflow

NCF: Specially designed for reflow process (Lower viscosity NCF).
Pre-bonding condition: 130 °C / 2 s
Reflow condition: 170 °C / 2 min + 190 °C / 2 min + 260 °C / 2 min
+ 190 °C / 2 min by convection ovens.

Void Suppression and making solder joint were successfully archived with the NCF by molded reflow process.
## CoW assembly by molded reflow

|               | Size : 7.3 mm × 7.3 mm, Thickness 100 μm  
Peripheral bump : 80 μm pitch, 328 pin  
Bump height :  
Cu Pillar (30 μm) + Sn/Ag Solder (15 μm) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top die</strong></td>
<td></td>
</tr>
</tbody>
</table>
| **Plated wafer** | 12 inch wafer, Thickness 250 μm  
Plating thickness :  
Cu 4 μm/ Ni 4 μm /Au 0.1 μm |
Chip on wafer: 421 dies
Gap between dies: 5 mm
Molding cap thickness: 300 μm

No die shift was observed.
3D die stacking TSV-PKG assembly by Molded reflow process

- Bumped wafer (Wafer for top & TSV die)
- Lamination
- Dicing blade
- Dicing
- Bonding tool
- Pre-bonding
- Plated wafer

- 3 die stacking (Under pre-bonding condition)
- Over-molding
- Reflow treatment

Chip on wafer: 421 × 3 = 1263 dies
Gap between dies: 5 mm

3 dies stacking CoW
X-ray image after over-molding

Full array bump area
Perf;eripheral bump area (staggered in two rows)

Observation from top view (3 die stacking)
Perspective view

No die shift was observed by over-molding.
Cross section of TSV-3D die stacking

Molding cap thickness: 500 μm

Cross section after reflow
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Bump stabbing assembly

**Conventional mass reflow process**

1. Flux apply

```
Flux
```

2. Pre-bonding

```
Wafer
Heater
```

3. Reflow

```
Wafer
Heater
Wafer
```

4. Flux cleaning

**Bump stabbing mass reflow process**

1. Pre-bonding

```
Bonding head
Wafer
Heater
```

2. Reflow

```
Wafer
Heater
Wafer
```

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Test vehicle specification

Bump stabbing

Top die

Bumps of the top die

Bottom die

Pads of the bottom die

TV die specifications

<table>
<thead>
<tr>
<th>Die</th>
<th>Size</th>
<th>Thickness</th>
<th>Bump pitch</th>
<th>Bump size</th>
<th>Bump height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top die</td>
<td>10 x 8 mm</td>
<td>0.725 mm</td>
<td>I/O: 40 μm, Dummy: 300 μm</td>
<td>Φ20 μm</td>
<td>Cu/Sn-Ag: 10 μm/8 μm</td>
</tr>
<tr>
<td>Bottom die</td>
<td>10 x 8 mm</td>
<td>0.725 mm</td>
<td>I/O: 40 μm, Dummy: 300 μm</td>
<td>Φ26 μm</td>
<td>Bottom/Stubbing: 2 μm/3 μm</td>
</tr>
</tbody>
</table>
Solder joint by bump stabbing

Stacked dies

Cross section of joint

Sn-Ni-Cu alloy was formed.
3D die stacking

Die thickness : 40 μm
Stack layer : 4

Solder joints were formed with good alignment

Cross section after reflow treatment

*Details will be presented at session 33-4 (3:30 pm on June 1)
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Consortium “JOINT” has been founded!

State of the art jisso technologies of material and equipment get together, which can provide the solution.
Summary

Enhancement of the productivity of high density interconnection was studied and demonstrated, which were related 2.5D and 3D packages.

- BFL film: Side by side multiple die TCB gang bonding
- Molded reflow: CoW multiple die bonding including 3D die stacking
- Bump stabbing process: 3D die stacking
- Expanding film
- RDL first FO
- Consortium “JOINT”
Thank you!