Compression Molding for Large Area Fan-Out Wafer/Panel Level Packaging

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Outline

- Motivation for Panel Level Packaging
- Embedding
  - Equipment for large area Compression Molding
  - Materials for Panel Level Embedding
  - Panel Compression Molding Results
- Summary & Outlook
FOWLP/FOPLP Process Flow Options

Mold first

1. Apply thermal release tape on carrier
2. Die assembly on carrier
3. Wafer/panel overmolding
4. Carrier release
5. RDL (e.g. thin film, PCB based, …), balling, singulation

RDL first

1. Apply release layer on carrier
2. RDL (e.g. thin film, PCB based, …)
3. Die assembly on carrier
4. Wafer/panel overmolding
5. Carrier release, balling, singulation
PANEL LEVEL MOLD EMBEDDING
Compression Molding - Principle

process principle

- Short cycle time
- Constant temperature -> no heating or cooling ramps
- No full compression pressure over longer time
- PMC and mold release extra process steps

process profile

2 – 15 min
APIC YAMADA’S History of WLP & Panel Molding


Si chip

150mm          200mm          300mm          300mm          600mm

MS-W030M       WCM-150/220HP  WCM-300MS      LPM-600

WCM-100         WCM-300L/G   LPM-600 AUTO SYSTEM COMING SOON

150mm          200mm          300mm          300mm          600mm

2.5D            TSV (3D)


WCM

LPM
LPM-600 Manual (Semi-Auto) System

Applicable size: \(~670\times620\ \text{mm}^2\)

Productivity: 5 panels/hour

*depending on cure time

Features:
- 4-servo motor precision press
- 1,764KN Clamping force
- Auto Film handler (FAME)
- Vacuum molding
- Capable for both TOP and BTM cavity configuration
High Accurate Parallelism /Clamp Control

Accurate Parallelism control by independent 4-motor direct driven clamping mechanism
Variable Clamp-Speed Control

Clamp speed = Compound velocity

- Clamp speed = Compound velocity

**Toggle Press**

- Compound flow velocity (acceleration)
- Constant closing velocity

**Direct drive press**

- Clamp speed (variable)
- Optimum
- Constant compound flow velocity
- Minimum 1/100 mm/s
LPM-600 Full Auto System (2 presses)

- Panel handler (Robot)
- Panel rotate unit
- Panel loader
- Film loader
- On- loader
- Off- loader
- SRB unit option
- Press ※2sets
- Granular Dispenser
- Film cutting unit

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Molding Compounds for Large Area Encapsulation

**Liquid Compression Molding Compounds**
- Standard material for wafer level embedding
- Paste-like material is dispensed in the cavity and flows during tool closing and compression of the tooling
- Limited potential for large area due to complex dispense patterns needed and longer flow length?
- €€

**Granular Compression Molding Compounds**
- Standard material for MAP compression molding
- Granular material is distributed nearly homogeneously all over the cavity and melts and the droplets have to fuse during closing and compression of the tooling
- No limitations for large area application
- €

**Sheet Lamination Molding Compounds**
- Standard material for wafer level embedding
- Material sheets are melting and only flow around dies for encapsulation
- Sheets in defined thicknesses/volume
- No limitations for large area application
- €€€
Material Evaluation for Compression Molding

<table>
<thead>
<tr>
<th>properties</th>
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<th>B</th>
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<tr>
<td>filler content</td>
<td>89 wt.-%</td>
<td>90 wt.-%</td>
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<tr>
<td>filler cut size</td>
<td>75 µm</td>
<td>55 µm</td>
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<tr>
<td>CTE$_1$</td>
<td>7.5 ppm/K</td>
<td>7.2 ppm/K</td>
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<tr>
<td>CTE$_2$</td>
<td>33 ppm/K</td>
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<tr>
<td>T$_g$</td>
<td>165°C</td>
<td>175°C</td>
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<tr>
<td>flexural modulus @ RT</td>
<td>22 GPa</td>
<td>27 GPa</td>
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<tr>
<td>mold temperature</td>
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<tr>
<td>inmold cure time</td>
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<td>420 s</td>
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<tr>
<td>PMC temperature</td>
<td>125°C</td>
<td>125 h</td>
</tr>
<tr>
<td>PMC time</td>
<td>1 h</td>
<td>2 h</td>
</tr>
</tbody>
</table>

- Comparable cured material properties
- Comparable low mold and cure temperature but different cure times
- Significant different flow properties with much lower viscosity of the liquid compound
Mold Compound Application

Liquid EMC

- Dispensing of dot patterns
- Volume control by insitu weighing

Granular EMCs

- Homogeneous spreading
- Volume control by weighing
- Manually by sieve technology, automatically by vibrating unit
Compression Molding on 12”/300 mm Wafer Size

Liquid EMC

- Dispensing of one dot in the center
- Homogeneous filling without flow marks or knit lines

Granular EMCs

- Homogeneous spreading
- Homogeneous filling without flow marks or knit lines
Compression Molding on 24”x18” Panel Size

Liquid EMC – Evaluation of dot size pattern

- Evaluation of different dot patterns – target panel thickness of 450 µm (~ 250 g)
- Dispense time with state of the art material and equipment 20 – 30 min
Compression Molding on 24”x18” Panel Size
Liquid EMC – Evaluation of dot size pattern

1. Strong flow marks and knit lines
2. Strong flow marks and knit lines
3. Strong flow marks and knit lines
   - Panel broken along knit line
4. Strong flow marks and knit lines

- Complete filling of the 24”x18” panel feasible
- Strong flow marks and knit lines for all patterns, dispense time too long
- Process and material optimization needed
Compression Molding on 24”x18” Panel Size
Granular EMC – Evaluation of spreading

- Evaluation of two different spreading patterns – target panel thickness of 450 µm (~ 250 g)
  - Dot pattern
  - Homogeneous spreading
- Application time with state of the art material and manual equipment 5 – 10 min
Compression Molding on 24”x18” Panel Size
Granular EMC – Evaluation of spreading

- Complete filling of the 24”x18” panel feasible
- Granular compound distribution has also an influence on flow marks
  - Homogeneous distribution of the compound required

Flow marks in the shape of the granular dot pattern

No flow marks
Compression Molding on 24”x18” Panel Size

Molding of panels with assembled dies
(die thickness: 250 µm, mold thickness: 450 m)

- Molded panels with liquid EMC show less flow marks as blank panels
- Significant marks only visible at the panel edges where no dies are assembled

- Encapsulation of assembled panels with liquid and granular compound feasible
- Granular EMC show slightly better mold results and shorter process time

- Molded panels with granular EMC show nearly no flow marks
SUMMARY & OUTLOOK
RDL on Panel Size – Quo Vadis?

PCB based technologies
- Already available on panel level – proof of concept has been demonstrated
- Currently limited to 10 µm lines and spaces
- Maskless adaptable processes possible
- No die surface opening possible for e.g. sensors or LEDs
- Low cost potential

Thin film technologies
- Proven and established process for FOWLP
- Fine line structuring down to 2 µm lines and spaces
- Die surface opening possible for e.g. sensors or LEDs
- Quite expensive equipment

- No simple upscaling of technologies from WL to PL
- Not one solution for everything
- Application defined – “best of both worlds”
- New materials in combination with new processes must be developed
IZM Panel Level Embedding Line from Wafer Scale to Panel Scale 610 x 456 mm²/24”x18”

Placement → Accuracy → Molding → Lamination → Laser Drilling

Placement:
- Datacon evo/ASM Siplace CA3
- Mahr OMS 600/IMPEX proX3
- WL: Towa up to 8”
- PL: APIC up to 18”x24” incl. 12” WL
- Lauffer/Bürkle
- Siemens Microbeam/Schmoll Picodrill with HYPER RAPID 50

Mech. Drilling → Sputter → Cu Plating → Imaging → Etching

Mech. Drilling:
- Schmoll MX1
- CREAMET 600 CI 2 S3
- Ramgraber automatic plating line
- Orbotech Paragon Ultra 200

Etching:
- Schmid
Summary Wafer to Panel Size for Fan-out Packaging

Wafer Technologies

6”
8”
12”
300 mm

PCB Technologies

24” x 18”
610 x 457 mm²

Panel Technologies
Thanks for your attention!