Wafer Level Encapsulation - an Alternative Format for Discrete Packaging: Its Challenges and Solutions

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Market Place An Update
Why Large Format Packaging (LFP) Will Become Increasing Important?
Drivers of Large Format Packaging (LFP)

- Value Adding
  - More than Moore
  - Package level system Integration
    - less board space required
- Handling critical quartet of APT
  - Performance
  - Form factor
  - Reliable
  - Cost
- 4th Wave of SC
  - Internet of Things
  - Big Data

Advanced Packaging Platforms

**Advanced SiP**
(QFN/MIS, WLP and Laminate based)

Source: Yole

“SiPlization”
ASM Total Solution for WLP & PLP Technology

1. Pick n Place
2. Molding
3. Ball Drop
4. Singulation
5. WLP Inspection, Test & Packing

5S/6S protection to prevent electrical short for small discrete
1) Ball formation by Ball Drop or Paste Printing (Dek)

2) Wafer Pre-cut by blade or Grooving by laser (ALSI)

3) Front & Back sides wafer (8” & 12”) level molding (ORCAS)

4) Final package singulation with mold compound remain at the package edges for protection (Laser 1205)

5) Wafer level test / finishing to T&R with 6 sides quality inspection (Sunbird)
Concept of CCCV 1/

- Cost effective design, Cost effective solution, Cost-to-deliver Value for customers.
- Critical quartet of CCCV are:
  - Multi-functional with increase performance
  - Reliability
  - Form factor,
  - Cost efficiency

Concept of CCCV 2/

- Clamping edge
- Keep-out-zone (KOZ) product
- Cap shoulder
- Over-mold (Over Size molding) product
Flexibility of Mold Tooling

Compression Molding Concept: Die Up/Down/KoZ/Over Mold

- **Die Up type**
  - Mold cap area > substrate area
  - Keep-out-zone (KOZ) method

- **Die Down type**
  - Mold cap area < substrate area

Over-mold method

CONFIDENTIAL
KoZ & Overmold Molding

KOZ molding

Overmolding

Co-planarity
CLAPsys™ for Total Thickness Control

The co-planarity range of both 8” and 12” products is well within 0.02mm.
Warpage Management Discussion

Warpage Management 1/

- Encapsulant Design
  - Filler Loading
  - Filler Size
  - CTE $\alpha_1/\alpha_2$

![Graph showing Filler content and CTE comparison]
Warpage Management 2/

- Encapsulant Design

Substrate With No Feature Below X-Y Plane
Warp: -1mm

Substrate With Feature Below X-Y Plane
Warp: -4mm

Substrate With Feature Below X-Y Plane
Warp: -1mm

Warpage Management 3/

- PMC Profiling
  - Ramp Rate
  - Hold Period
  - Cooling Rate
- Dead weight
  - Physical dead
  - Spring load
  - Interleaf

Encapsulant Cure State After Molding

Encapsulant Cure State After Post Mold Curing
Warpage Management 4/

- Temperature vs. Time
- Ramp-up
- Holding
- Cool-down
- With Dead Weight

Warpage Control: PMC

- Before TMC
- After TMC
- MC ~ 410 μm
- MC ~ 145 μm

Graph showing warpage before and after TMC treatment.
Warpage of KOZ Molding

Warpage immediately after molding.

Thin Mold Cap and Dispensing
Thin Mold Cap

- Definition for our work:
  - Mold cap thickness $\ll 200 \, \mu\text{m}$
- Challenges:
  - Granular Vs Liquid
  - Cover of encapsulant over the substrate
  - Flow Mark
  - Dispensing quantity
  - Trench depth
Dispensing: Factors 1/

- Dispensing Patterns
  - Definition:
    - Glob
    - Line
    - Circular (or serpentine)
    - Star
  - When to apply such patterns:
    - White space
    - Trench depth
    - Complexity of package
    - Mold cap thickness

Dispensing: Results 2/

Co-planarity
Ø8” WLP

Thickness (µm)
- A35
- A60
- A70
- A80
Other Moldability

Delamination

- Factor to consider before, during and after mold
  - pre-treatment, molding process and de-molding
Voiding

- Factor to consider before and during molding
  - Tool design, pre-treatment, and molding process
    - Air Vent
    - Mini Vacuum Chamber
    - Vacuum is Key Points

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Summary of Work
Summary of Work 1/

- Large format packaging is a cost-effective packaging solution to produce encapsulated 5S or 6S packages.

- Achieving TTV of 20 µm of co-planarity for LFP is possible with closed loop automated co-planarity monitoring within the encapsulation system.

- Key factors for warpage control are:
  - Encapsulant design
  - Post mold cure with profiling and dead weight
  - Ratio of Encapsulant versus Silicon

Summary of Work 2/

- Thin mold cap of << 200 µm is achievable via:
  - Suitable liquid encapsulant
  - Different variant of dispensing pattern

- Delamination and voiding is controllable with proper before and during molding.
  - Plasma cleaning
  - Pre-baking
  - Optimal molding process control

- Encapsulation System is available for mWLCSP 5S/6S
Laser Dicing for mWLCP

Multi Beam Laser Dicing of Molded WLCSP

- Narrow dicing width
- Accuracy
- No Delamination
- Fast
- Reliable
Laser Versus Mechanical Blade Dicing

- Too wide
- High blade wear
- Chip-out
- Delamination
- Reliability
- Slow

Multiple Beam Machine

- Patented Multi Laser Beam
- DOE – Diffractive Optical Element
  - Beams: > 2
  - Distance: 10 - 1000 µm
  - Ø Beam: 8 µm
  - Accuracy: 1.5 µm (Left and Right)

- Active Mounts for Vibration Compensation
  (IP propriety)

- 300 mm wafer Stage
Impact of Beam Size

Single Beam versus Multi Beam

Intensity (a.u.)

Groove width (µm)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

Single beam grooving
ALSI Multi beam
Ablation threshold
HAZ single beam 8-10 µm
HAZ ALSI < 5 µm

Coating Requirement 2/

Figure 2: Coatings forms as the energy is transferred in various layers. Coatings form as the energy is transferred in various layers. Coatings form as the energy is transferred in various layers.
Wafer Edge Considerations

- Manufacturing (Expose Edge)
  1. Mechanical trim after Molding or…..
  2. Molding with a Keep Out Zone (KOZ)

- Alignment on the Blade Half Cuts that are now exposed on edge

Keep it out Zone (KOZ) molding
Exposed Edge

Expose the edge for future alignment

Requirement for New Alignment Methodology

Exosed or Mechanically trimmed edge with depth of 110 µm

Challenges:
- Dicing street is not visible (70 – 100 µm mold compound is not transparent)
- Bumps placement does not have good accuracy 2 - 3 µm accuracy
Off Center can cause Delamination

Alignment needs to look at all lanes on edge of Wafer

Edge trajectory
Edge alignment (Close-up)

Edge alignment image captured around the perimeter of the wafer.

Alignment algorithm processes the image and identifies the correction.

Need Sufficient Lighting (Ring-led) for Kerf Check

Ring LED Side Light with Diffuser

Align on Kerf
Ideal Dicing Kerf

- Straight
- No chip-out
- No delamination
- Passes reliability tests
- Productivity

Chip-out Is A Challenge for Laser Dicing

Chip-out strongly depends on filler size. Larger the filler size, larger the mouse bite, e.g., Chip-out is equal to half diameter of Filler Fused silica.
Result of Laser Dicing 2/

Results
- Dicing width: 14 µm
- Mold compound remain: 19 µm
- Depth: 180 µm
- Productivity: 1.5 wafers per hour
- Average fillers 15 µm, max. up to 30 µm

Process parameters
- \( \lambda = 355 \text{ nm} \)
- Passes: 2 passes
- Laser power = 3.3 to 3.8 W
- Speed = 90 mm/s up to 300 mm/s
- DOE: 16UV20

Results
- Dicing width: 14 µm
- Mold compound remain: 19 µm
- Depth: 180 µm
- Productivity: 1.8 wafers per hour
- Average fillers 15 µm, max. up to 30 µm

Process parameters
- \( \lambda = 355 \text{ nm} \)
- Passes: 10 passes
- Laser power: 4/3.5/3.5 W
- Speed: 67 mm/s up to 450 mm/s
- DOE: 12UV50

200 mm 180 µm thick mold compound
Die pitch: 628 µm x 328 µm

300 mm 300 µm thick mold compound
Die pitch: 6198 µm x 5953 µm
Figure 7: Confocal image on sidewall
Figure 8: Average sidewall roughness < 1 µm

WPH Comparison Between Competing Dicing Technology

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<tr>
<th></th>
<th>ASMPT</th>
<th>SAW</th>
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<tr>
<td>Dicing Width (µm)</td>
<td>18</td>
<td>&gt;20</td>
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<tr>
<td>UPH * (WPH)</td>
<td>2.7</td>
<td>1</td>
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<tr>
<td>Cost ($/wafer)</td>
<td>12</td>
<td>20</td>
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- Separation technology comparison for m-WLCSP
  - Mold Cap thickness <350um on a SQ 2.8mm die size on a Ø 300mm wafer.
Summary of Work

- This work had used following optimized processes to dice through mWLCSP package:
  - Multi Beam Laser Dicing for faster dicing
  - Special optics (Multiple Beams) to reduce Kerf Width
  - Flexibility to use different Optics to increase dicing speeds while keeping a narrow kerf
  - Several Alignment Options
  - Special Coating material for better adhesion to prevent damage to the package

- These processes have allowed users to have smaller dicing widths and higher throughputs than Blade Dicing.
- In sum, Laser provide a good alternative to mechanical saw for narrow wide dicing < 20 µm.

Thank you for the Invitation & Listening!