ASM

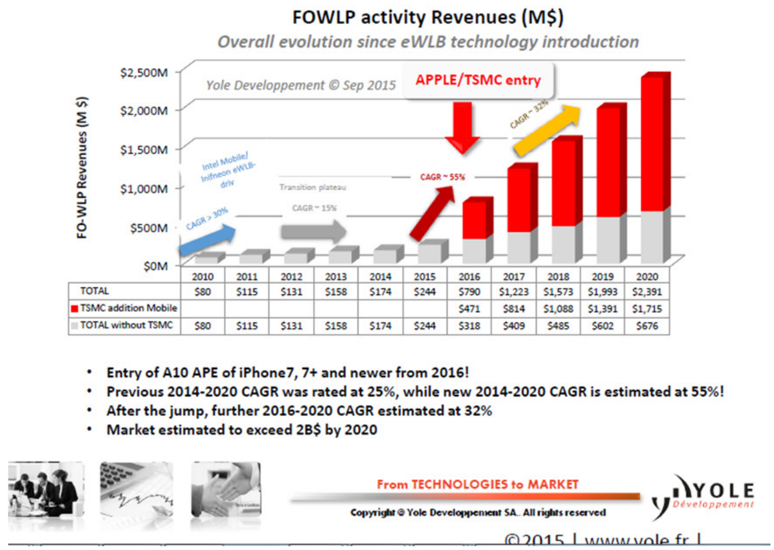
Wafer Level Encapsulation - an Alternative Format for Discrete Packaging: Its Challenges and Solutions

Eric Kuah

Market Place An Update

CONFIDENTIAL

FOWLP Potential



FOWLP activity Revenues (M$)

Overall evolution since eWLB technology introduction

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL	$80	$115	$131	$158	$174	$244	$790	$1,223	$1,573	$1,993	$2,391
🟥 TSMC addition Mobile							$471	$814	$1,088	$1,391	$1,715
▨ TOTAL without TSMC	$80	$115	$131	$158	$174	$244	$318	$409	$485	$602	$676

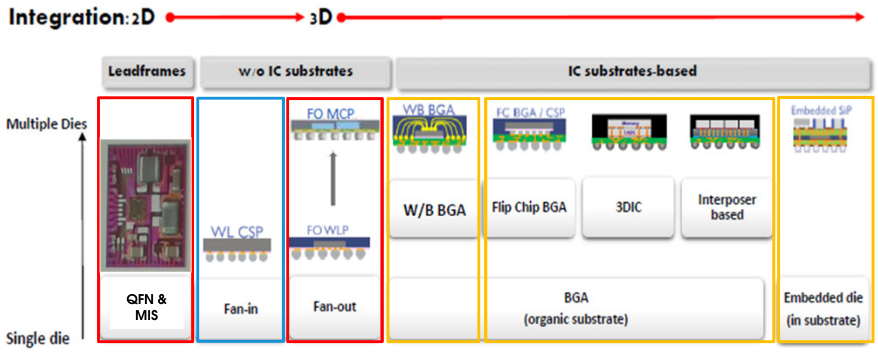
- **Entry of A10 APE of iPhone7, 7+ and newer from 2016!**
- **Previous 2014-2020 CAGR was rated at 25%, while new 2014-2020 CAGR is estimated at 55%!**
- **After the jump, further 2016-2020 CAGR estimated at 32%**
- **Market estimated to exceed 2B$ by 2020**

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

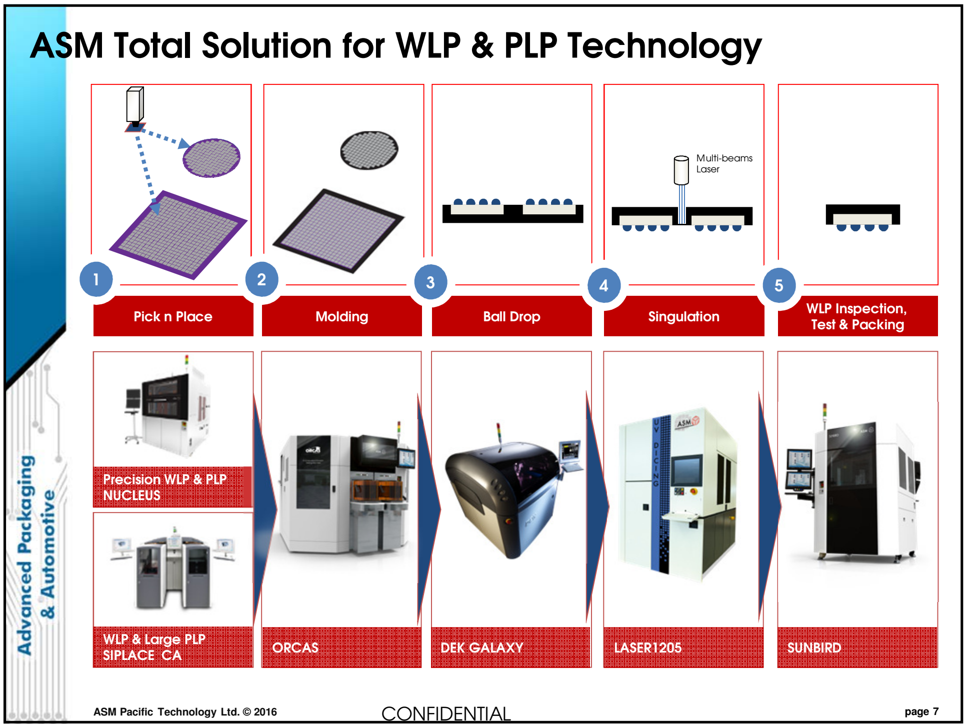


Advanced SiP
(QFN/MIS, WLP and Laminate based)

Complexity: Increased functionality, I/Os, integration complexity

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

Precision WLP & PLP NUCLEUS

WLP & Large PLP SIPLACE CA

ORCAS

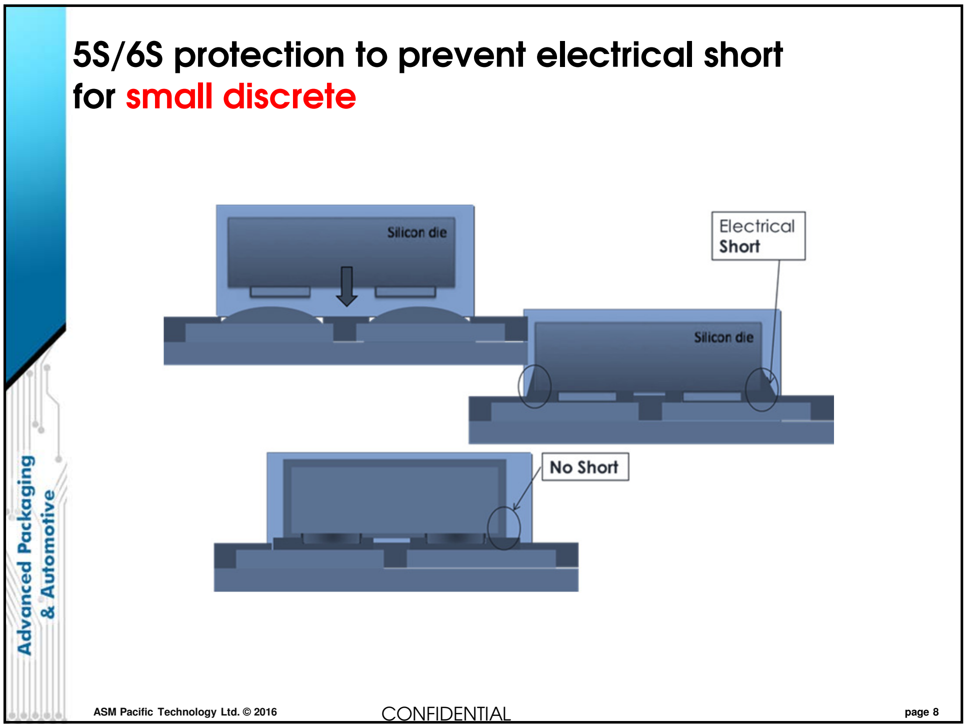
DEK GALAXY

LASER1205

SUNBIRD

Advanced Packaging & Automotive

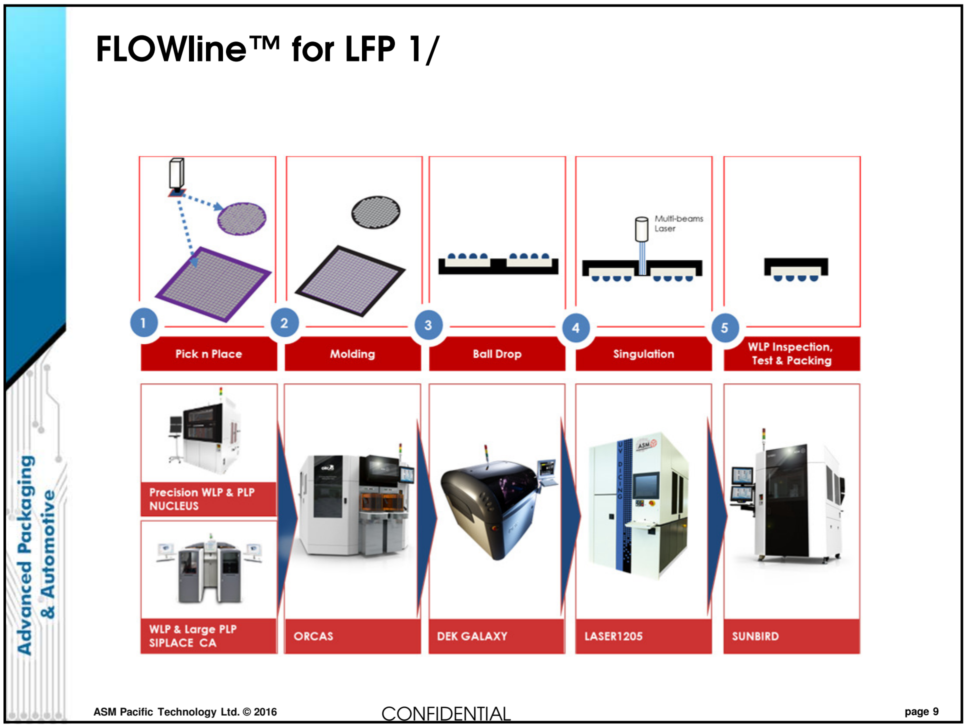
CONFIDENTIAL



5S/6S protection to prevent electrical short for small discrete

Advanced Packaging & Automotive

CONFIDENTIAL



FLOWline™ for LFP 1/

1 Pick n Place

2 Molding

3 Ball Drop

4 Singulation

5 WLP Inspection, Test & Packing

Precision WLP & PLP NUCLEUS

WLP & Large PLP SIPLACE CA

ORCAS

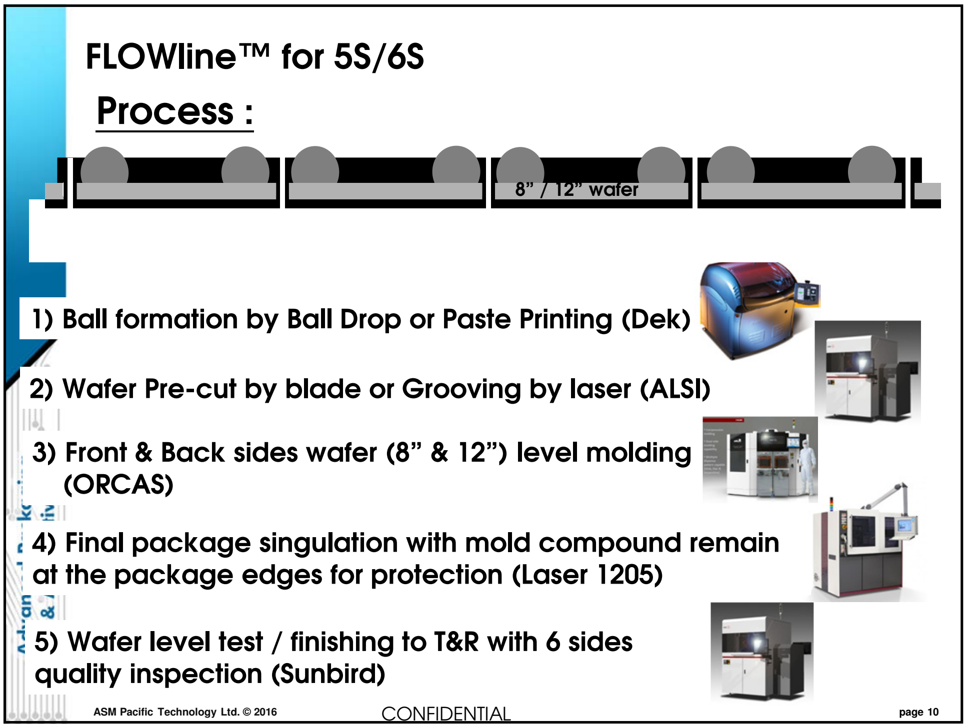
DEK GALAXY

LASER1205

SUNBIRD

Advanced Packaging & Automotive

ASM Pacific Technology Ltd. © 2016 CONFIDENTIAL page 9



FLOWline™ for 5S/6S

Process :

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)

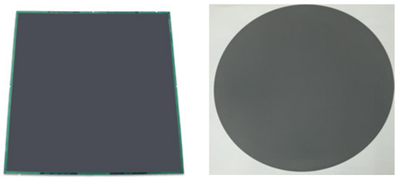
5) Wafer level test / finishing to T&R with 6 sides quality inspection (Sunbird)

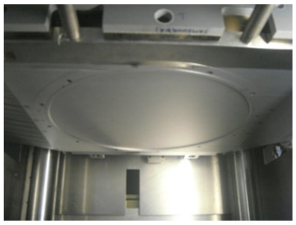
ASM Pacific Technology Ltd. © 2016 CONFIDENTIAL page 10

Concept of CCCV 1/

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

Concept of CCCV 2/

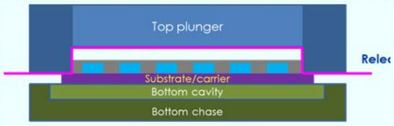




Flexibility of Mold Tooling

Advanced Packaging & Automotive

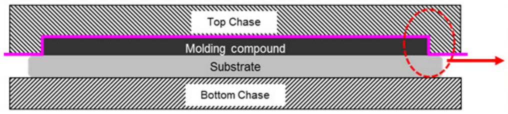
Compression Molding Concept: Die Up/Down/KoZ/Over Mold

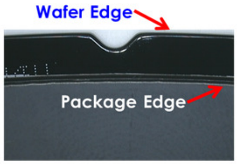


Die Up type

Die Down type

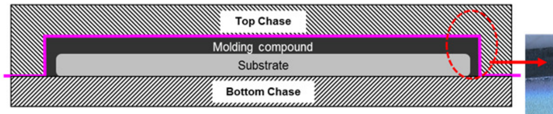
Mold cap area > substrate area

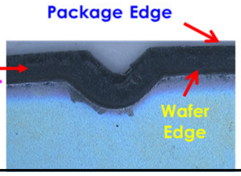




Keep-out-zone (KOZ) method

Mold cap area < substrate area





Over-mold method

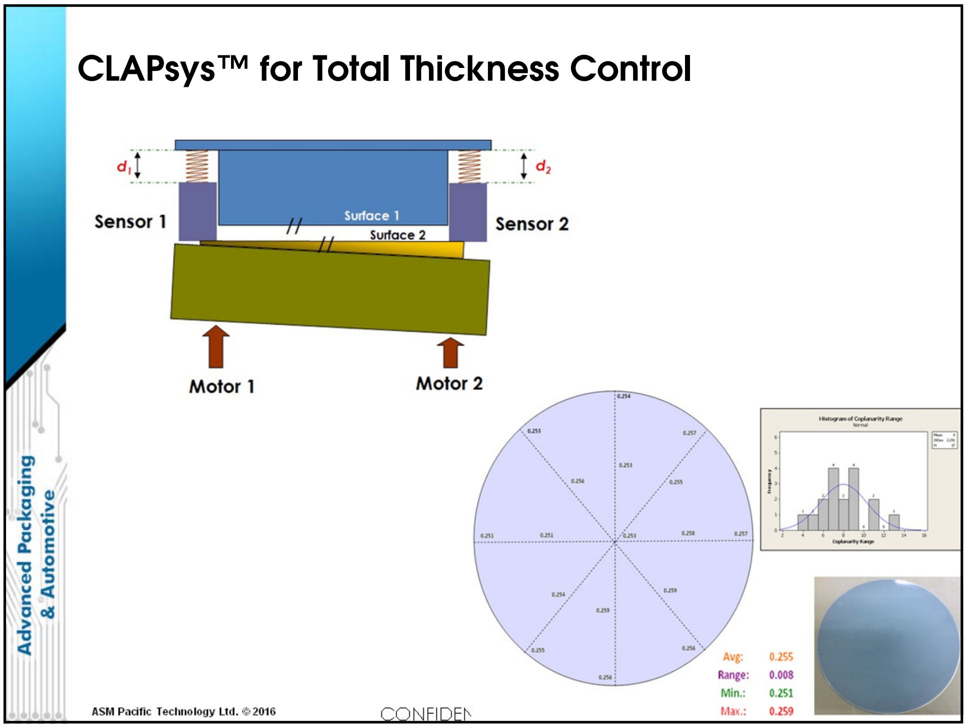
Advanced Packaging & Automotive

KoZ & Overmold Molding

KOZ molding

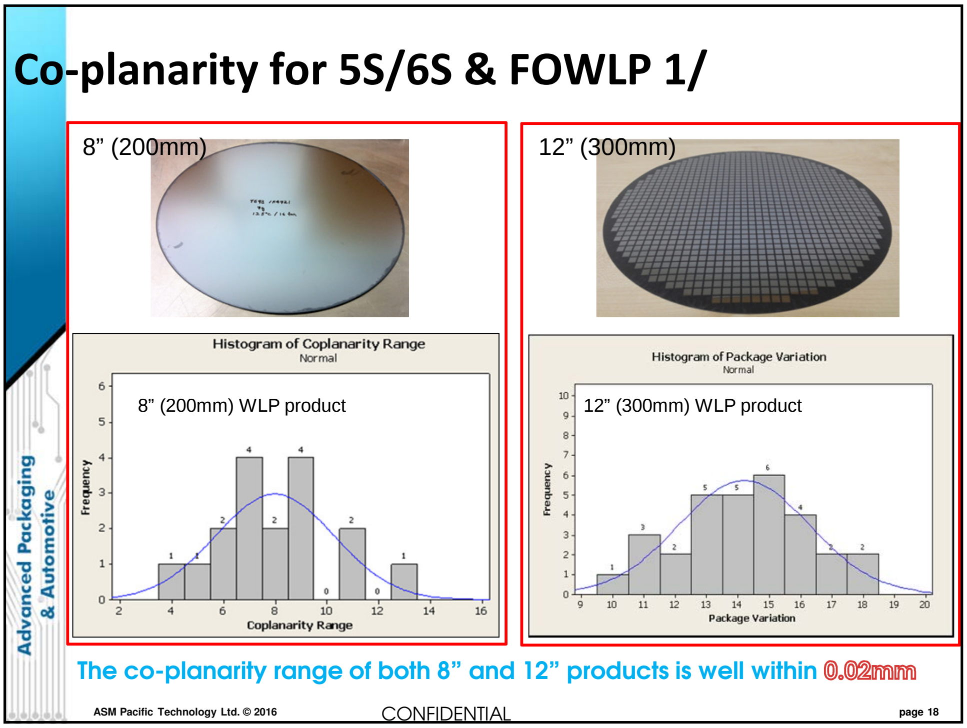
Overmolding

Co-planarity



CLAPsys™ for Total Thickness Control

Avg: 0.255
Range: 0.008
Min.: 0.251
Max.: 0.259



Co-planarity for 5S/6S & FOWLP 1/

8” (200mm)

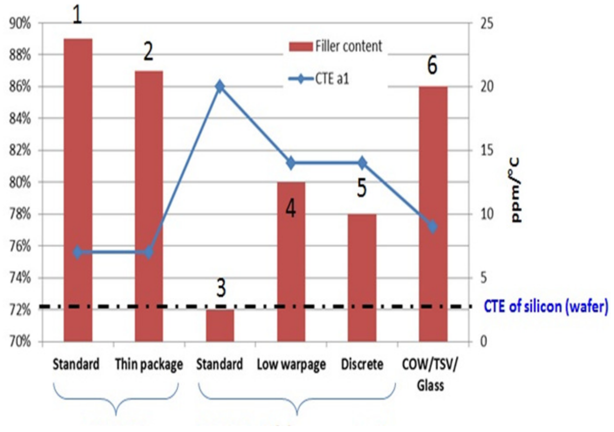
12” (300mm)

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

Warpage Management Discussion

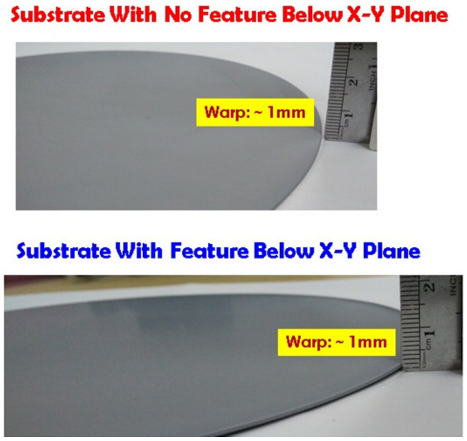
Warpage Management 1/

- Encapsulant Design
  - Filler Loading
  - Filler Size
  - CTE a1/a2



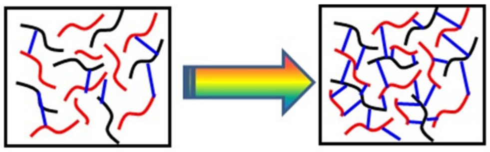
Warpage Management 2/

- Encapsulant Design



Warpage Management 3/

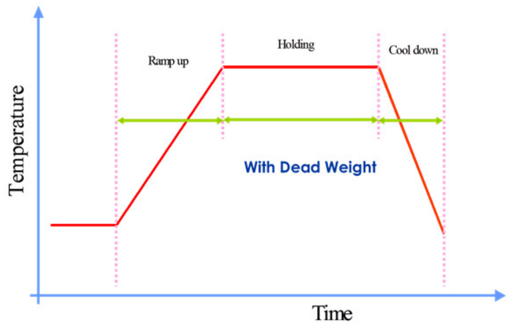
- PMC Profiling
  - Ramp Rate
  - Hold Period
  - Cooling Rate
- Dead weight
  - Physical dead
  - Spring load
  - Interleaf

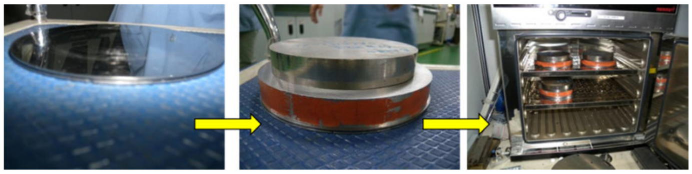


Encapsulant Cure State After Molding

Encapsulant Cure State After Post Mold Curing

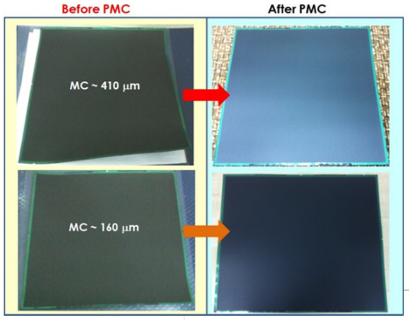
Warpage Management 4/

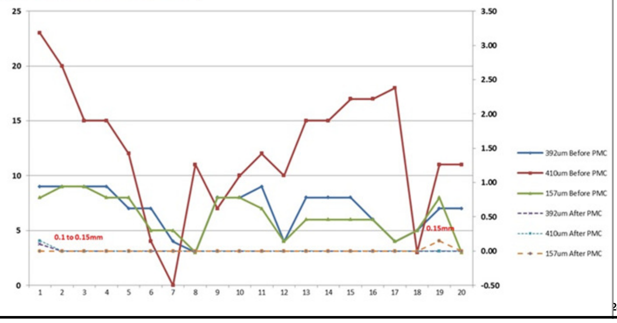




CONFIDENTIAL

Warpage Control: PMC





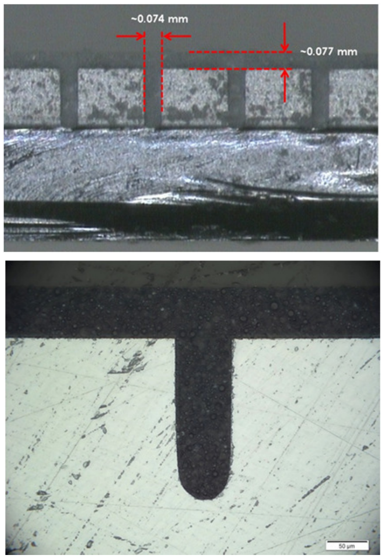
Warpage of KOZ Molding

Warpage immediately after molding.

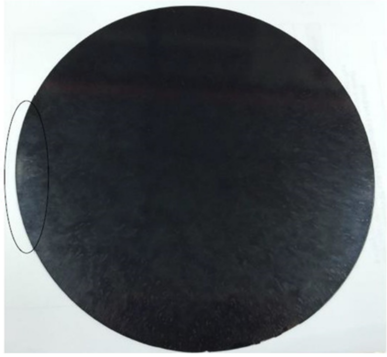
Thin Mold Cap and Dispensing

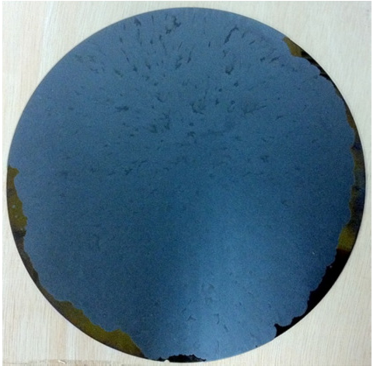
Thin Mold Cap

- Definition for our work:
  - Mold cap thickness << 200 μm
- Challenges:
  - Granular Vs Liquid
  - Cover of encapsulant over the substrate
  - Flow Mark
  - Dispensing quantity
  - Trench depth



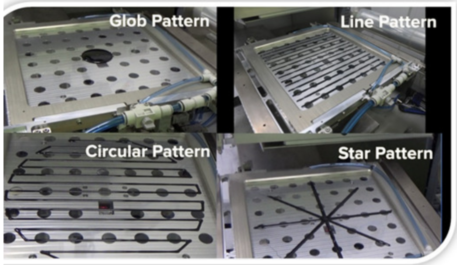
Thin Mold Cap: Type of Encapsulant

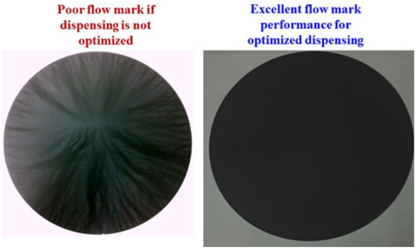




Dispensing: Factors 1/

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

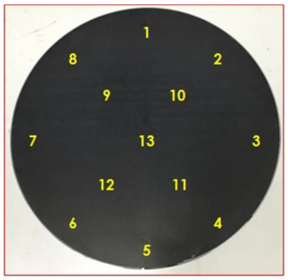


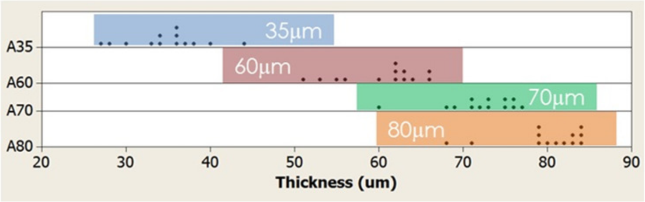


Dispensing: Results 2/

Co-planarity

Ø8" WLP

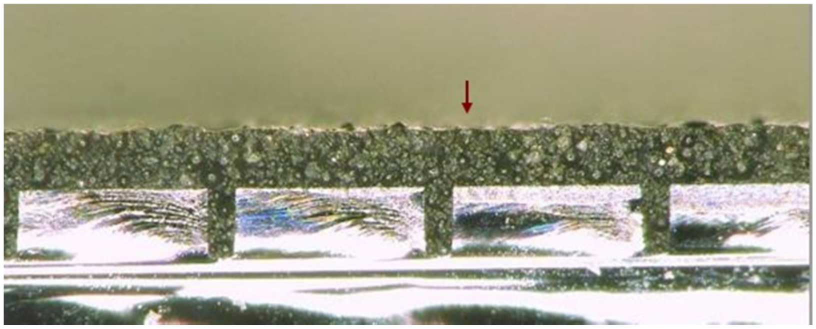




Other Moldability

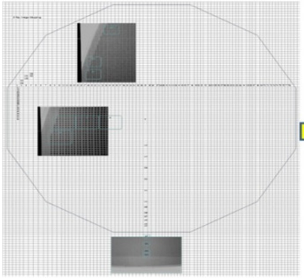
Delamination

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

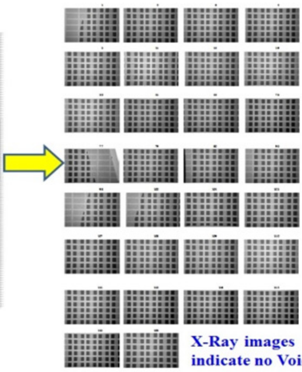


Voiding

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



Wafer map where X-Ray inspection is performed



X-Ray images indicate no Voids

Summary of Work

Summary of Work 1/

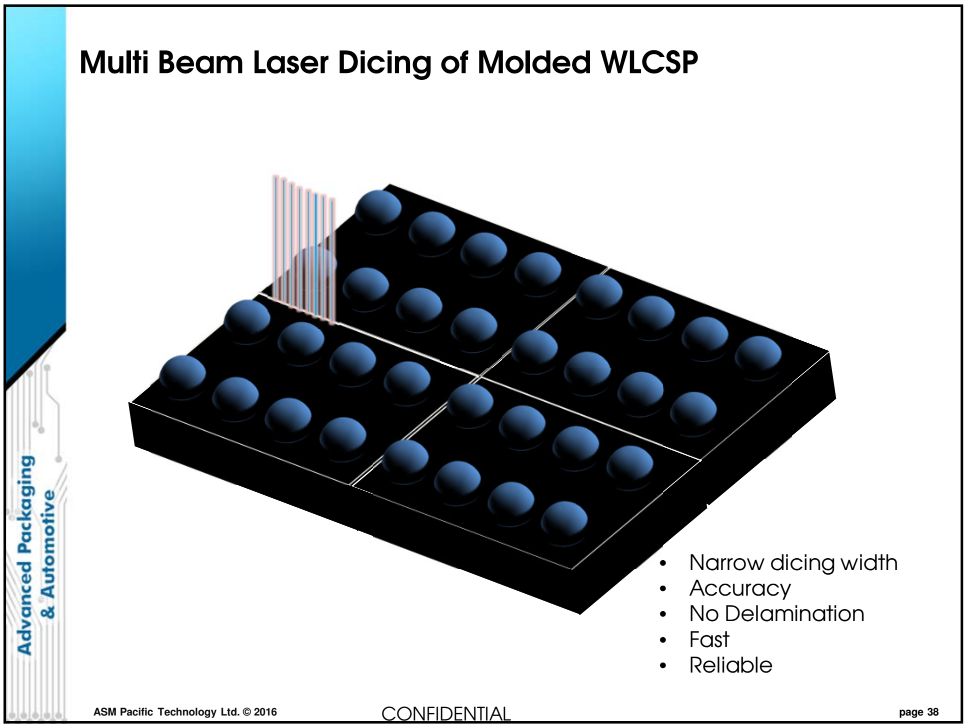
- ☐ Large format packaging is a cost-effective packaging solution to produce encapsulated 5S or 6S packages.
- ☐ Achieving TTV of 20 μm of co-planarity for LFP is possible with closed loop automated co-planarity monitoring within the encapsulation system.
- ☐ Key factors for warpage control are:
  - ■ 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

Advanced Packaging
& Automotive

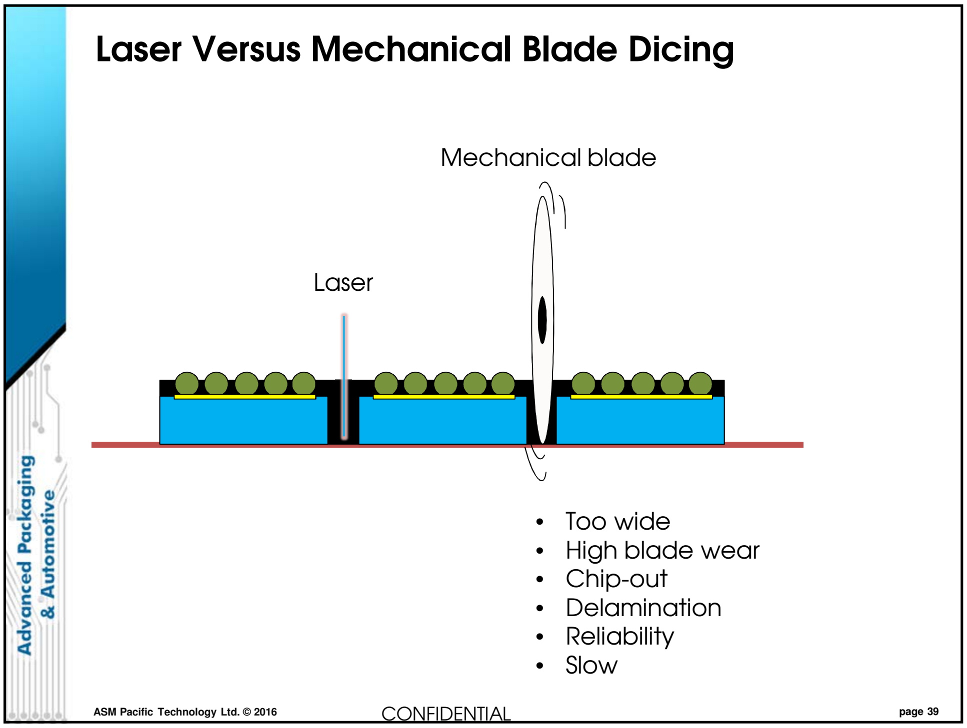
Laser Dicing for mWLCP



Advanced Packaging
& Automotive

Multi Beam Laser Dicing of Molded WLCSP

- Narrow dicing width
- Accuracy
- No Delamination
- Fast
- Reliable



Laser Versus Mechanical Blade Dicing

Mechanical blade

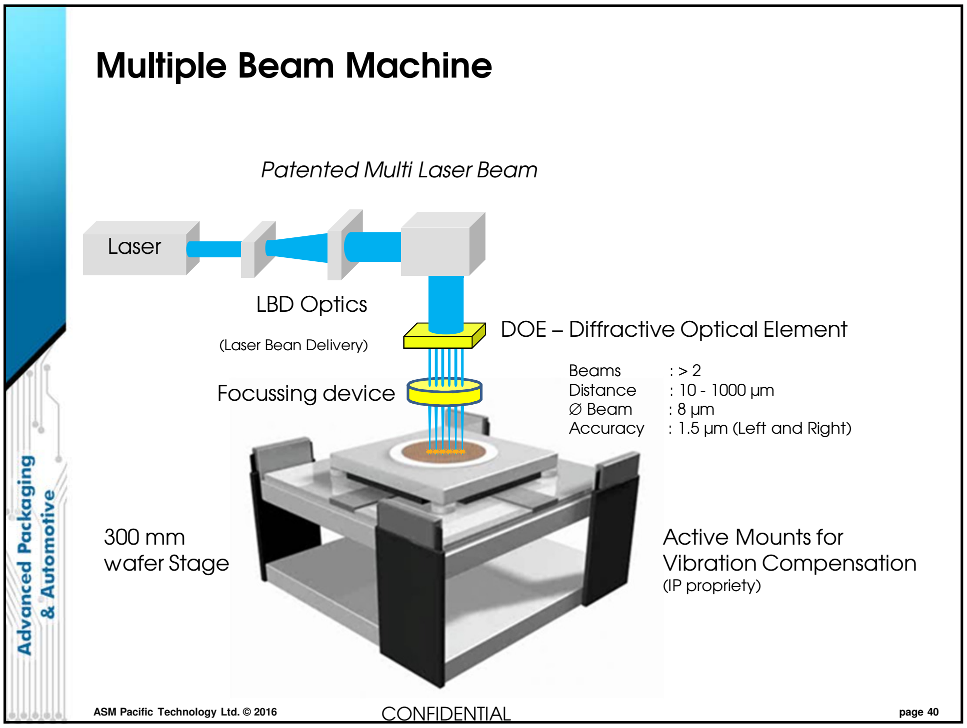
Laser

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

Advanced Packaging & Automotive

CONFIDENTIAL

page 39



Multiple Beam Machine

Patented Multi Laser Beam

Laser

LBD Optics

(Laser Bean Delivery)

DOE – Diffractive Optical Element

Beams : > 2
Distance : 10 - 1000 µm
∅ Beam : 8 µm
Accuracy : 1.5 µm (Left and Right)

Focussing device

300 mm
wafer Stage

Active Mounts for
Vibration Compensation
(IP propriety)

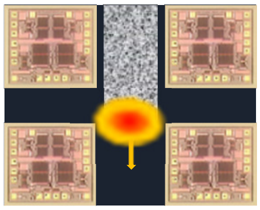
Advanced Packaging & Automotive

CONFIDENTIAL

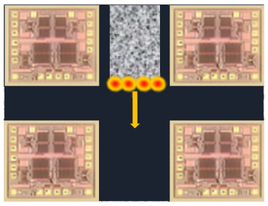
page 40

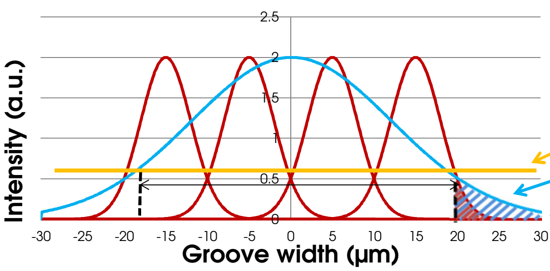
Impact of Beam Size

Single Beam Multi Beam



versus





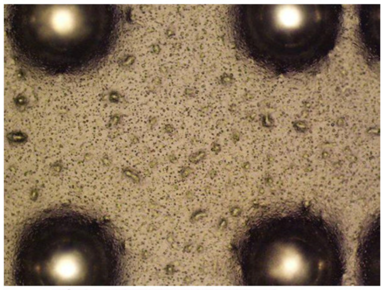
- Single beam grooving
- ALSI Multi beam

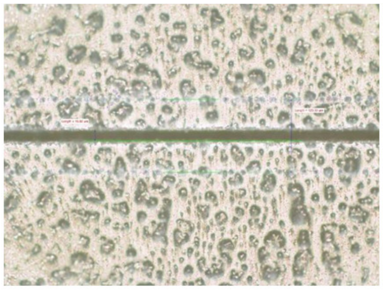
Ablation threshold

HAZ single beam 8-10 µm

HAZ ALSI < 5 µm

Coating Requirement 2/





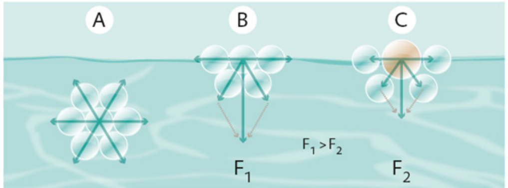


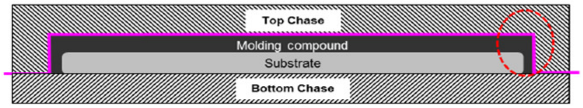
Figure 3: Interactive forces at the water/air interface or water/air/surfactant interface.
(A) - Inside the liquid, the attraction forces between the molecules cancel each other out. (B) - At the surface the resulting force (surface tension) is directed towards the interior of the liquid. (C) - A surfactant reduces this force (surface tension).

Wafer Edge Considerations

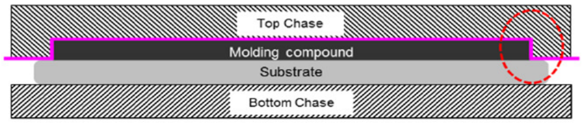
- Manufacturing (Expose Edge)
  1. Mechanical trim after Molding or…..
  2. Molding with a Keep Out Zone (KOZ)
- Alignment on the Blade Half Cuts that are now exposed on edge

---

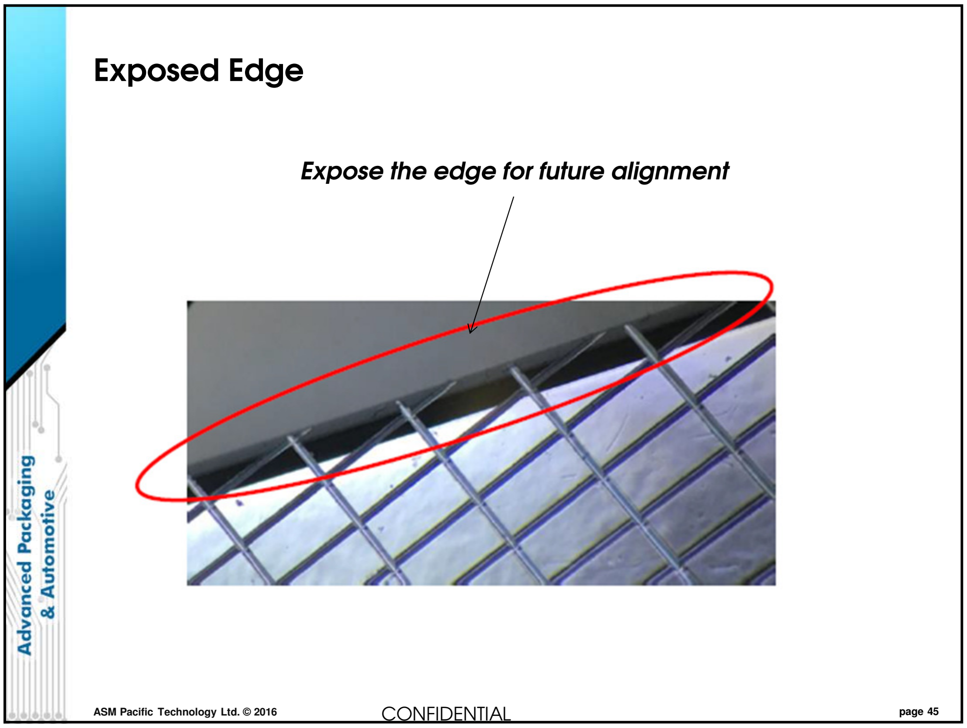
Keep it out Zone (KOZ) molding



Over-mold tooling



KOZ tooling

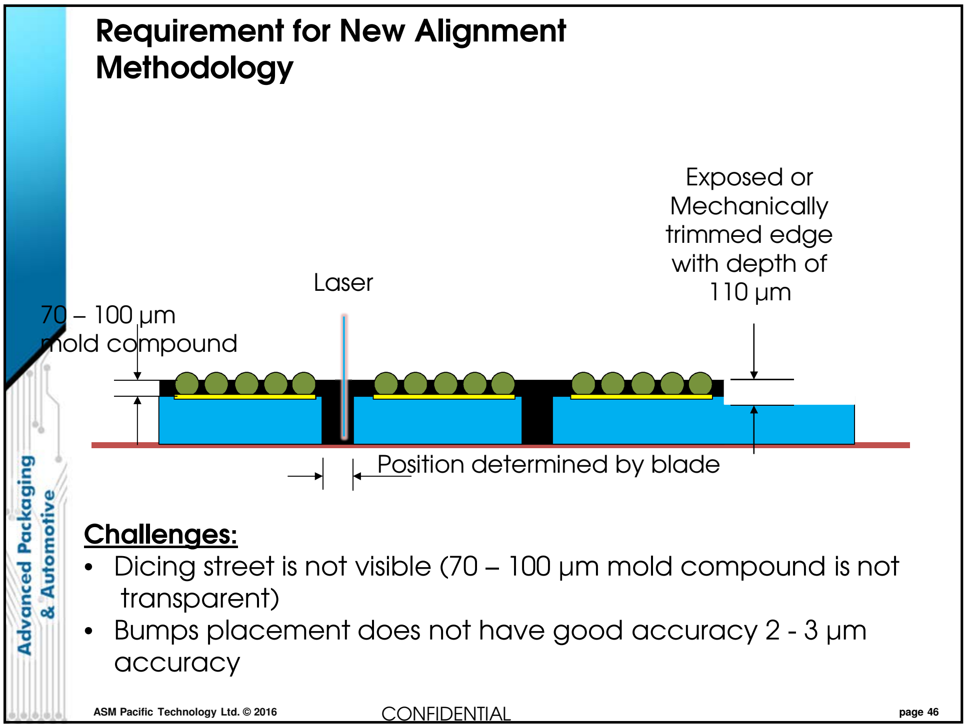


Advanced Packaging & Automotive

Exposed Edge

Expose the edge for future alignment

CONFIDENTIAL



Advanced Packaging & Automotive

Requirement for New Alignment Methodology

Exposed or Mechanically trimmed edge with depth of 110 µm

Laser

70 – 100 µm mold compound

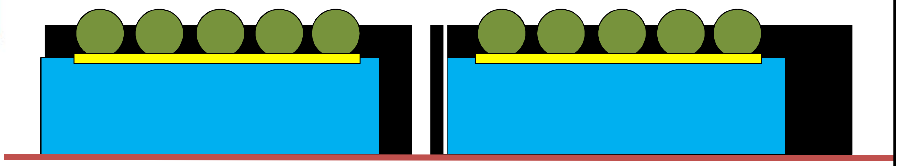
Position determined by blade

Challenges:

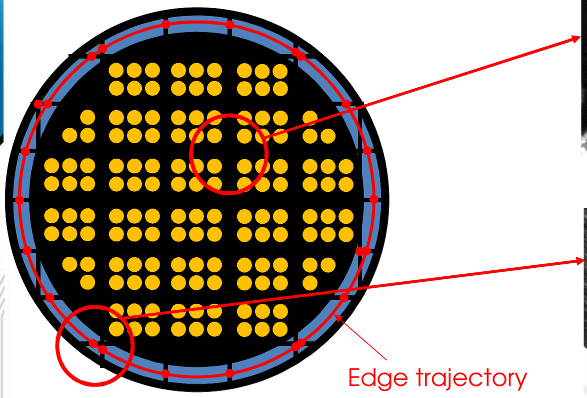
- Dicing street is not visible (70 – 100 µm mold compound is not transparent)
- Bumps placement does not have good accuracy 2 - 3 µm accuracy

CONFIDENTIAL

Off Center can cause Delamination



Edge alignment on Half Cut Lanes Blade Diced



Alignment needs to look at all lanes on edge of Wafer

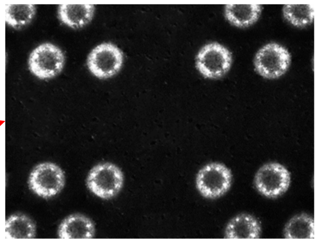


Figure 1: Bumps up image on dicing machine

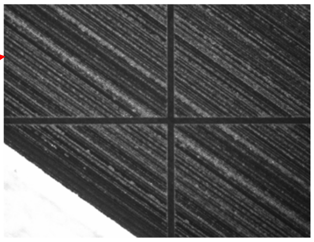
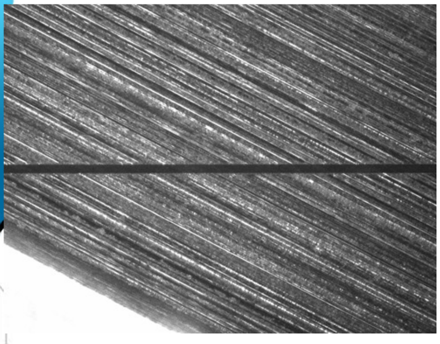
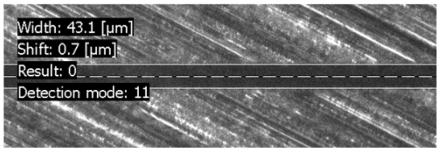


Figure 2: Image captured on the wafer edge with dicing machine.

Edge alignment (Close-up)

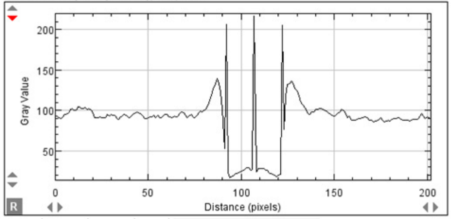


Edge alignment image captured around the perimeter of the wafer

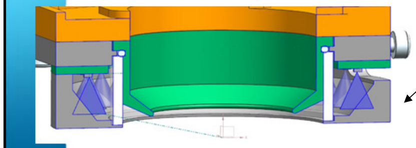


Width: 43.1 [µm]
Shift: 0.7 [µm]
Result: 0
Detection mode: 11

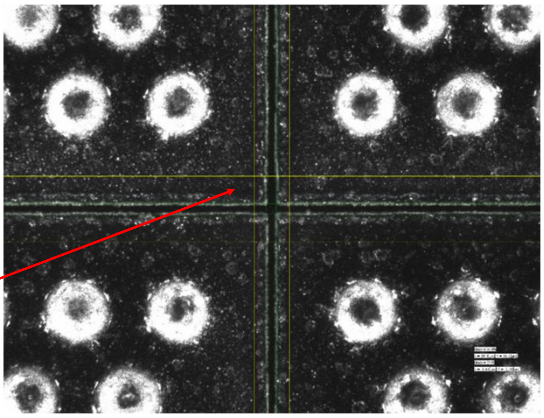
Alignment algorithm processes the image and identifies the correction



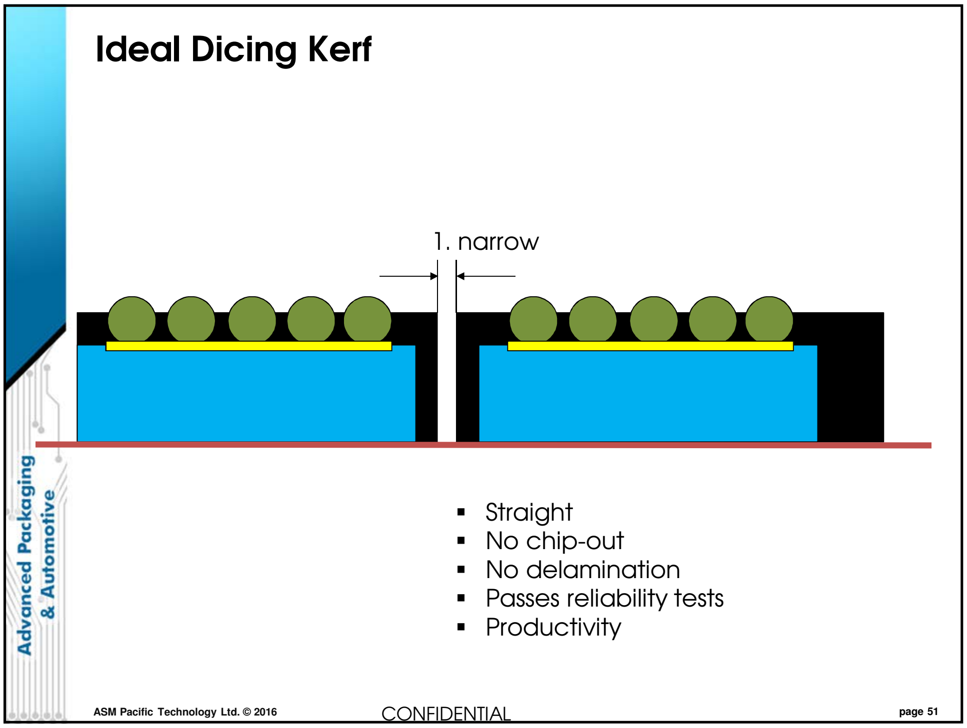
Need Sufficient Lighting (Ring-led) for Kerf Check



Ring LED Side Light with Diffuser

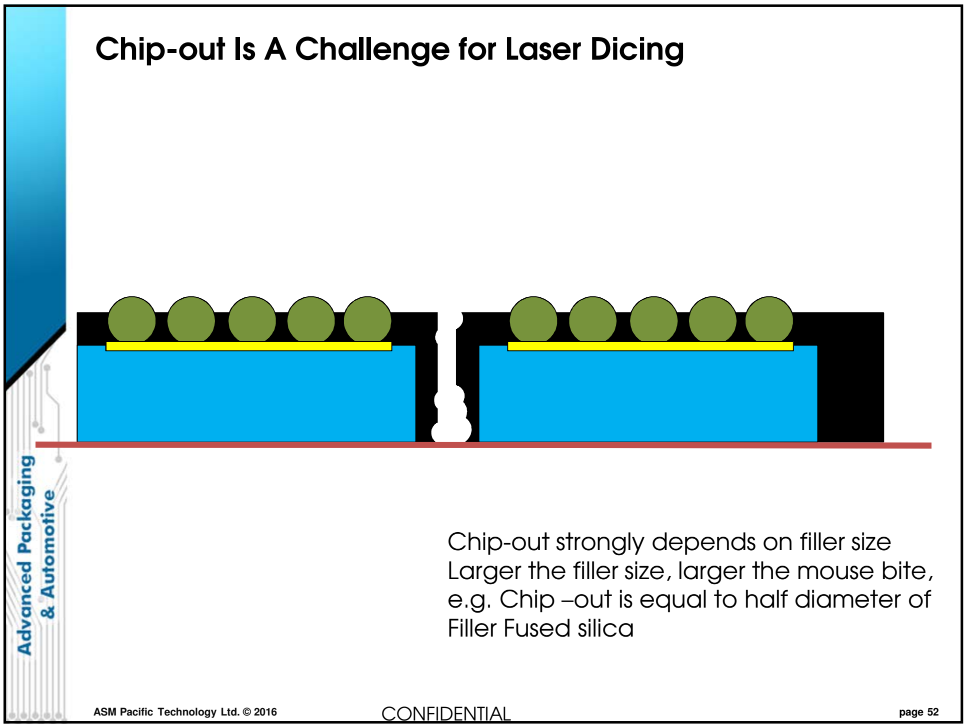


Align on Kerf



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 fillers15 µm, max. up to 30 µm

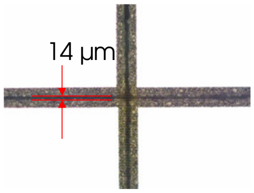


Figure 1: Microscope image focused on the top showing the dicing width and crossing

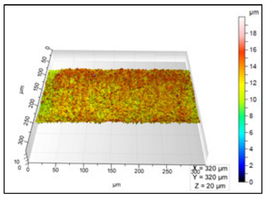


Figure 2: Confocal image focused on the sidewall

Process parameters

- λ = 355 nm
- Passes= 2 passes
- Laser power = 3.3 to 3.8W
- Speed = 90 mm/s up to 300mm/s
- DOE: 16UV20

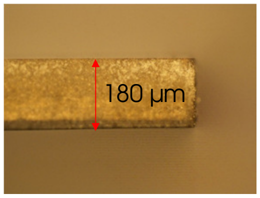


Figure 3: Microscope image focused on the sidewall.

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

Result of Laser Dicing 3/

Results

- Dicing width: 14 µm
- Productivity: 1.8 wafers per hour

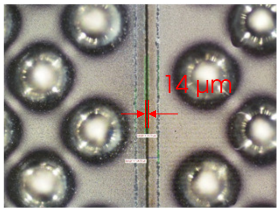


Figure 1: Microscope image focused on the top side showing the dicing width

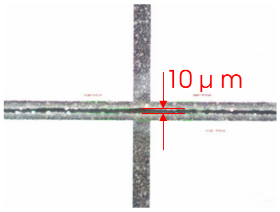


Figure 2: Microscope image focused on the back side showing the dicing width

Process parameters

- λ = 355 nm
- Passes: 10 passes
- Laser power: 4/3.5/3.5 W
- Speed: 67 mm/s up to 450 mm/s
- DOE: 12UV50

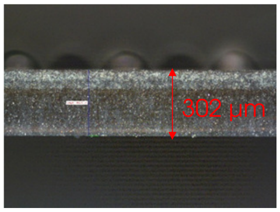


Figure 3: Microscope image focused on the sidewall

300 mm 300 µm thick mold compound
Die pitch: 6198 µm x 5953 µm

Attainable Ra For Diced Package Side Wall

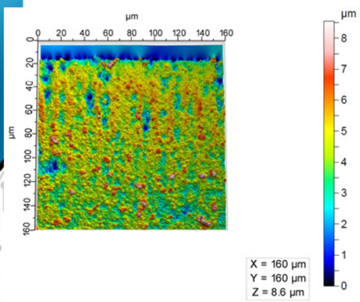


Figure 7: Confocal image on sidewall

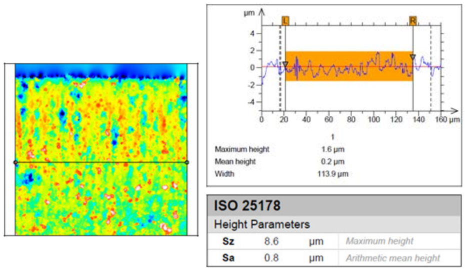


Figure 8: Average sidewall roughness < 1 µm

WPH Comparison Between Competing Dicing Technology

	ASMPT	**SAW**
Dicing Width (um)	18	>20
UPH * (WPH)	2.7	1
Cost ($/wafer)	12	20

- **Separation technology comparison for m-WLCSP**
  - **Mold Cap thickness <350um on a *SQ 2.8mm die size on a ∅ 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!