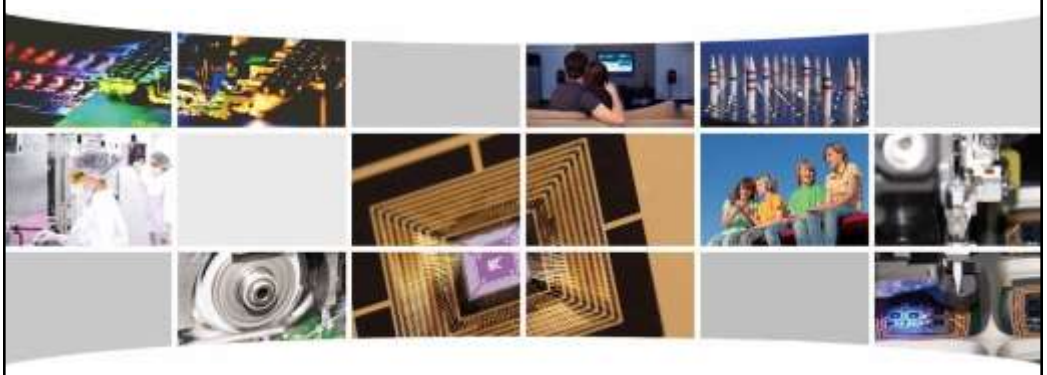


Kulicke & Soffa

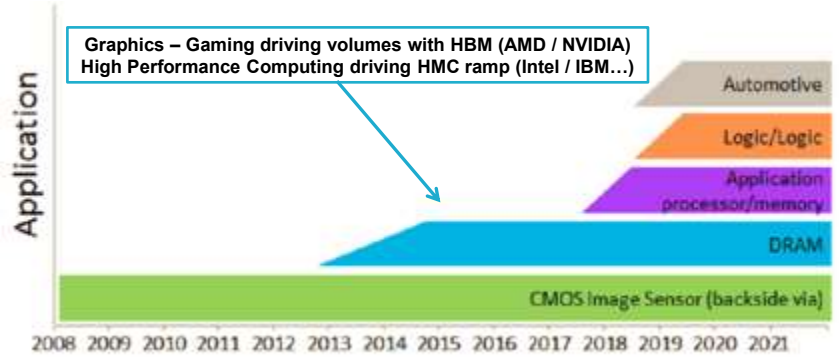
Flexible Manufacturing Platform for High Volume TCB and High Density FOWLP

Tom Strothmann
25 February 2016
IEEE CPMT SCV Meeting

Agenda

- Advanced Packaging Market Trends
- Flexibility of the APAMA Bonder Systems
- High Accuracy Flip Chip Die Placement
- FOWLP Die Placement Capability for C2W

3D IC with TSV Adoption Timeline



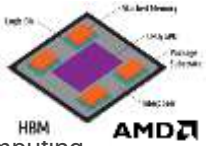
Source: TechSearch International, Inc.

- Image sensors with backside vias from Toshiba in January 2008, Sony CMOS image sensors + logic
- Tezzaron DRAM in 2013, Micron HMC, SK Hynix HBM, Samsung DIMM in 2015
- Logic on logic 2019 at the earliest
- Automotive (image sensor + logic) for safety reasons

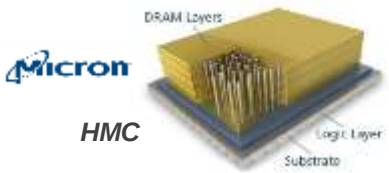
IEEE CPMT SCV - 25 Feb 2016 3

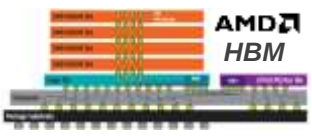
Packages Using Stacked Die

- Two of the leading edge stacked memory products are currently assembled using TCB and drive the highest demand
- ***High Bandwidth Memory (HBM)*** is used primarily for graphics applications
  - JEDEC standard for high density parallel interface
  - Assembled on interposers to enable high-density routing
  - HBM uses Chip-to-Wafer (C2W) TC bonders



- ***Hybrid Memory Cubes (HMC)*** are used in high-performance computing
  - High speed serial interface
  - Assembled on laminate with chip-to-substrate (C2S) TC bonders

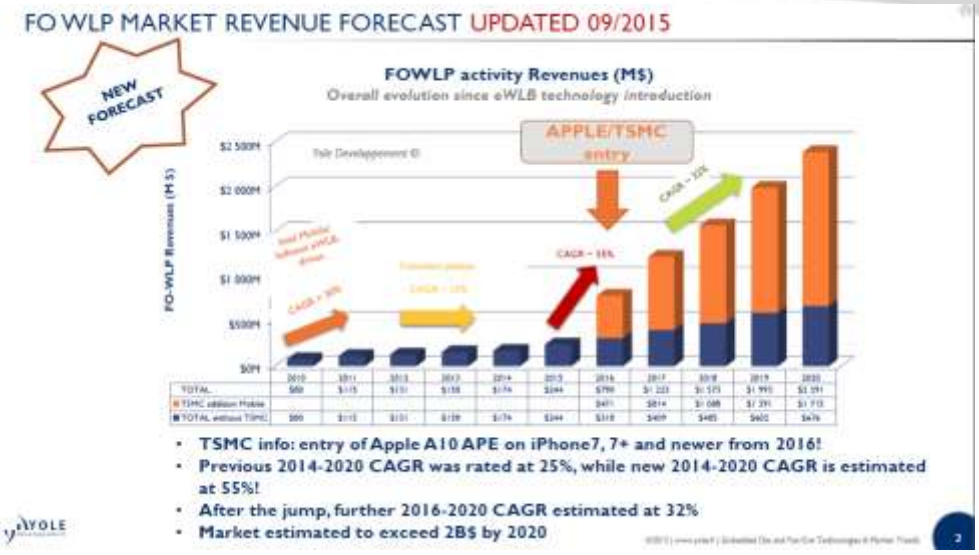




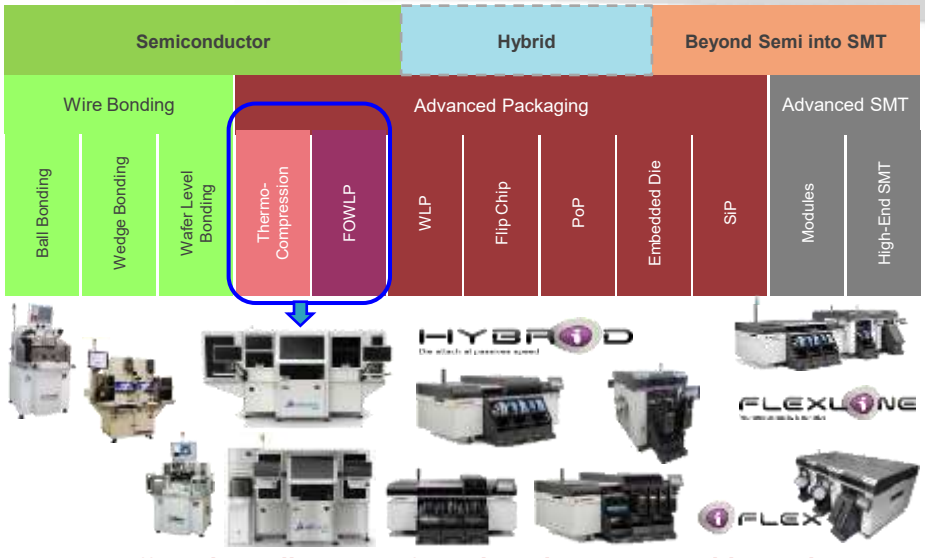
IEEE CPMT SCV - 25 Feb 2016 4

FOWLP Revenue Forecast

(source Yole Developpement)

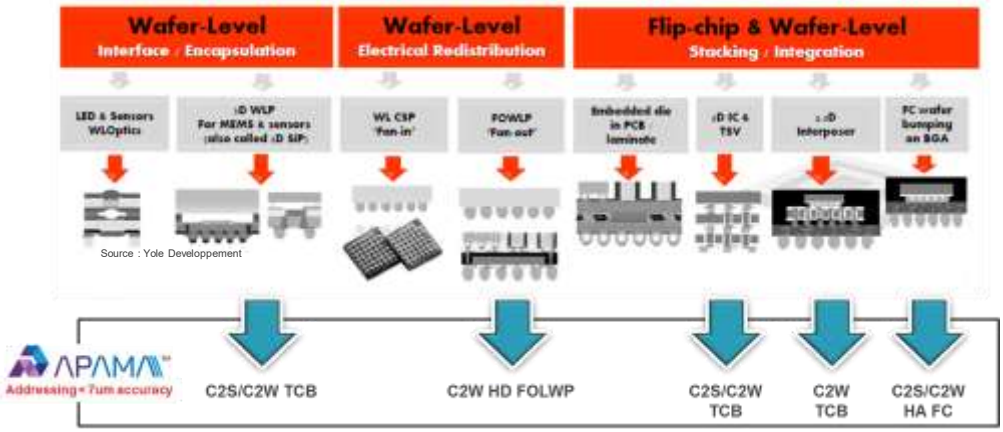


K&S Semiconductor Assembly Equipment



K&S Offers the Full Range of Semiconductor Assembly Equipment

APAMA Advanced Packaging Platforms



APAMA™ Thermocompression Bonders

APAMA C2S TC Bonder

APAMA C2W TC Bonder

- High Accuracy design of the APAMA TCB platforms enable high capability in adjacent markets
- Improved accuracy over existing die placement solutions
- C2S and C2W platforms can be adapted for High Accuracy Flip Chip die placement (HAFC)
- C2W platform can be adapted to FOWLP die placement
  - FOWLP die placement can be Face Up or Face Down

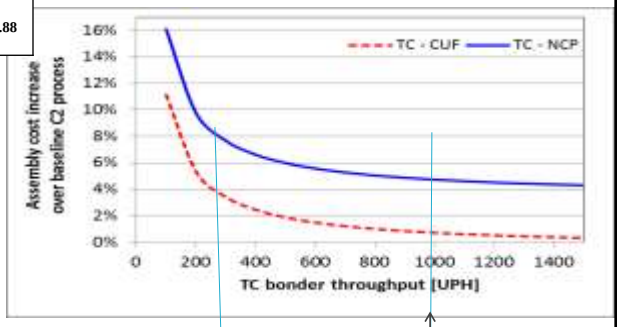
Assembly Cost as a Function of Throughput TCB Compared to Mass Reflow

	Die	Subst.	C2/TC	Other Assem.	Total
C2 - CUF	11.96	0.58	0.77	4.33	17.64
TC - CUF	11.96	0.58	0.84	4.29	17.67
TC - NCP	11.96	0.58	1.24	4.10	17.88

Savansys Cost Model

- Results show very little difference between mass reflow and thermo-compression
- Higher costs for TC-NCP is due to high materials cost - Material cost will go down during HVM transition

The Cost of TCB is Competitive at High UPH



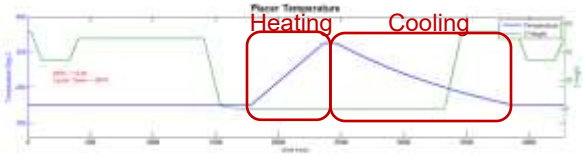
Today's TC Bonders Running in Production

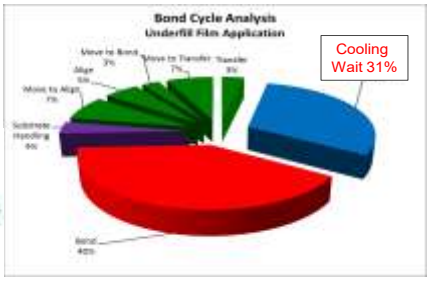
Small cost difference at 1000 UPH

IEEE CPMT SCV - 25 Feb 2016 9

High UPH TC Bonding (TC-NCF and TC-CUF)

- Optimize equipment design with guiding principals for movement efficiency
  - Bond head, die and target material movement during each cycle
- Maximize parallel functions in the process whenever possible
- Analyze and optimization of each program segment
- *Reduce the range of temperature cycling required by the bond head*
  - Temperature cycling is required for each die bond cycle
  - Reducing the range greatly improves the process UPH
  - Fast and linear heating (350°C/sec)
  - Slower and non-linear cooling (125°C/sec)
  - Consumes valuable process time
    - Conventional TC-NCF process ~30%





IEEE CPMT SCV - 25 Feb 2016 10

TCB Local Reflow Process Options

Process		Advantages	Disadvantages	UPH
Pre-applied Underfill	Paste (NCP)	• Die is underfilled during TCB • Mature process	• Potential tool contamination • Void-free underfill requires dwell • Longer bond times to ensure curing	• Current 1000+ • Future 1500
	Film (NCF)	• Die is underfilled during TCB • Less chance for tool contamination than paste • Hot transfer at 150C is now possible for high UPH	• Void-free underfill requires dwell • Large temperature changes required	• Current 1100+ • **Future 2000+**
No Pre-applied Underfill	Dip Flux	• No chance of tool contamination • Very short bonding process times • Low forces even for high bump counts	• Requires flux cleaning • Requires post-bond CUF • More stress on bonds before CUF • Cooling to < 80C at fluxing station	• Current 900+ • Future 1500
	Substrate Flux	• Fluxing processes demonstrated Very fast and very limited bond head temp changes per cycle	• Requires flux cleaning • Requires post-bond CUF • More stress on bonds before CUF	• Prototyped 1000+ • **Future 2500+**

High UPH process capability has been demonstrated for both NCF and Substrate Flux processes

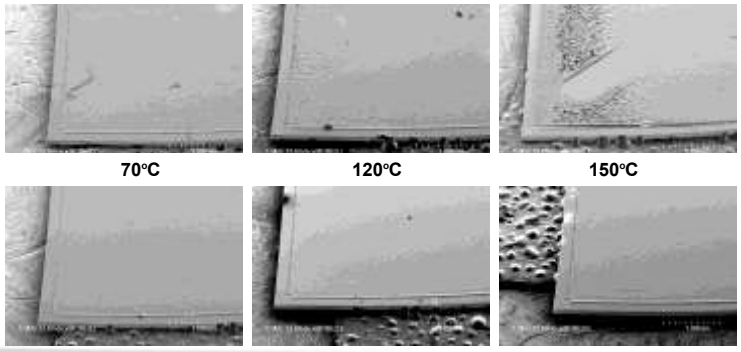
Improving NCF Throughput

- NCF has been limited to a die transfer temperature <80°C to avoid handling damage to the film when it becomes tacky
- New handling techniques have been developed to allow the NCF to be transferred at 150°C
- This improvement enables NCF to become one of the highest throughput options for stacked die TCB or die on interposer processes

Dual Head UPH
80°C = 1236
150°C = 1726

Pick Tool

Patent Pending

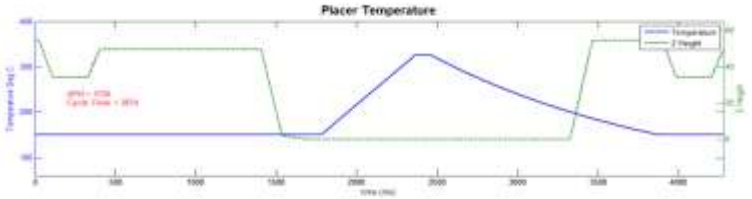


UPH NCF Hot Transfer Process

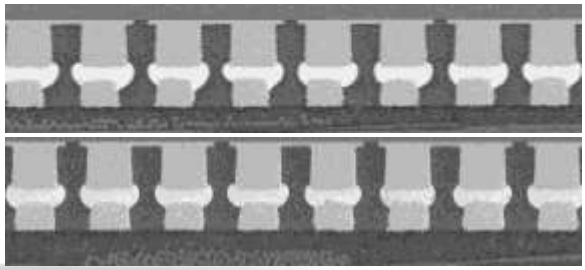
- Process without intermediate dwells achieves a UPH over 1700
- UPH is improved by 500 over the same process with an 80°C transfer temperature
- Assumes 80 die/strip (10 sites x 8 die stack)

Hot transfer 150°C

UPH: 1726
Cycle time: 3.9 sec



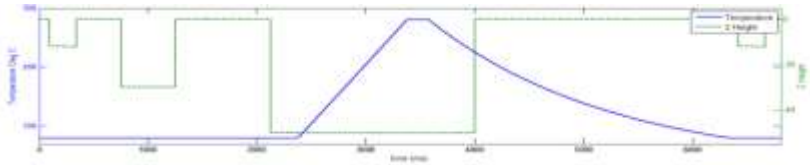
High speed NCF with excellent void performance and metallurgy



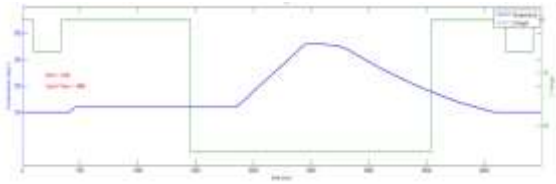
IEEE CPMT SCV - 25 Feb 2016 13

Substrate Fluxing for TC-CUF

- Dip fluxing TCB (thermocompression bonding) is a slow process for HVM
  - Die dipping in flux requires temperatures around 80ºC requiring bond head temperature excursions >200ºC.
  - Die dipping process is sequential to pick and bond adding >500ms to process.
  - Process demonstrated with as low as 6.9 sec cycle per unit equaling a UPH of ~1000



- Substrate fluxing is a fast process enabling a breakthrough for TCB
  - Without die flux dip the temperature excursion of bond head is limited to ~120ºC
  - Demonstrated a process with as low as 4.8 sec cycle per unit equaling a UPH of >1500
  - Potential to exceed 2500 UPH with higher temperature touch down



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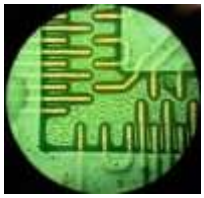
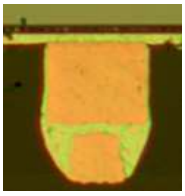
Substrate Fluxing UPH Improvement

- Flux application to the substrates has been validated with a unique printing method developed by Kulicke & Soffa
- Method applies the flux immediately prior to bonding and enables patterned flux printing
- Similar flux volume to that used in a conventional flux dip process
  - Limited flux volume ensures effective flux cleaning after bonding
- Process capability has been verified thorough SEM cross-section and bump metallurgy for several key factors in the process.
  - Flux volume applied to the substrate
  - Contact temperature of the die to the substrate
  - Die time at temperature prior to contact
  - Substrate time at temperature prior to bonding
- Two factors improve TC-CUF process UPH
  - Removing the sequential flux dip process
  - Enabling higher die transfer temperature

Printed Flux



300ºC Bond Temp



IEEE CPMT SCV - 25 Feb 2016 15

APAMA FACTS

Mitigate Uncertainty of Technology Shifts & Protect Your Investments

Flexible	Adaptable	Capable	Transformable	Scalable
				
Highly Configurable Core Design - TCB C2S - TCB C2W - HA FC - FOWLP - HA DA	**Adapt to Your Transforming Environment** - FOUNDRY - OSAT - IDM - R&D	**Quality and Output Performance** - Best UPH @ High Accuracy - Best in Class process monitors & Integrated Metrology - Best cost performance ratio	**An Evolutionary Core Machine that Protects Customer Investments** - TCB to FOWLP to HAFC - Risk free solution - Time to MFG	**K&S Global Infrastructure with Coverage for Sales/ Service/ MFG** - Repair/ refurbishment & warranty support - Global support presence - Supply ramp capacity

IEEE CPMT SCV - 25 Feb 2016 16

APAMA C2W Conversion Diagram

HAFC & FOWLP

TCB & FOWLP

Low Mass/Force Bond Head — Convertible — High Mass/Force Bond Head

Flux Dip — Select — Die Flip | Flux Dip — Select — Die Flip

HAFC & FOWLP (FD) Fastest

HAFC & FOWLP (FU) Fastest

TCB & FOWLP (FD) (Slower)

TCB & FOWLP (FU) (Slower)

Field Conversion Possible – Secure Investment

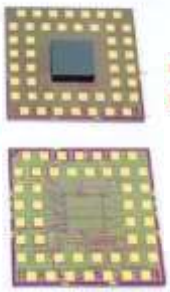
- Conversion is possible between process capabilities
- 70% CAPEX reduction compared to new equipment purchase
- Reduced CAPEX risk as market demands change

IEEE CPMT SCV - 25 Feb 2016 17

APAMA Platform Flexibility – HAFC
Extending Mass Reflow Capability

- Market is developing for High Accuracy Flip Chip placement (no TCB)
  - Accuracy of ± 3um (3500 UPH), ± 5um (4500 UPH)
  - Paired with mass reflow (MR) or laser reflow (LR – local reflow)
- Both C2W and C2S can be adapted to HAFC (reduced risk for capex)
  - Increased throughput is targeted to 4500 UPH
  - Active program for C2S with demo machines in application labs
- Demonstrated capability for C2W HAFC

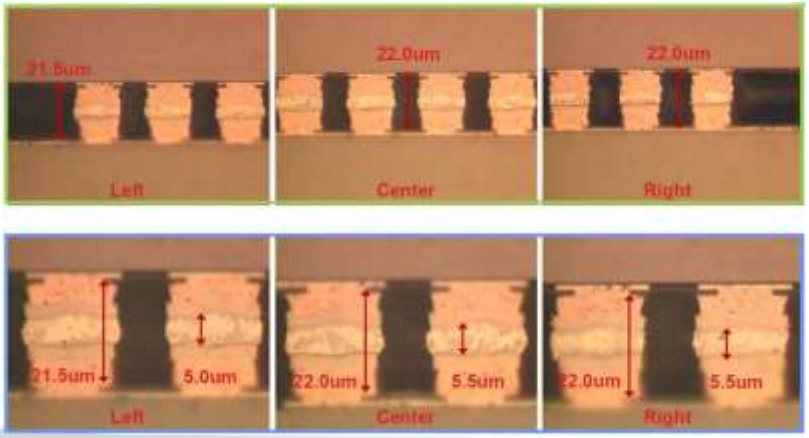
- Top Die
  - Length (X): 5.1mm
  - Width (Y): 5.1mm
  - Thickness (t): 700um
  - Bump height: 13um
  - Bump pitch: 30um
  - I/O: 3200



- Wafer Thickness: 700um
- Landing Die Area
  - Length (X): 16mm
  - Width (Y): 16mm
  - Pad height: 8.5um
  - Pad pitch: 30um

Si to Si 30um Pitch TV MR (3200 I/O)
Cross-section Inspection

- Accurate placement of die enables self-alignment during the reflow process
- Example is silicon to silicon so CTE is matched
- Assembly onto laminate needs to account for CTE mismatch

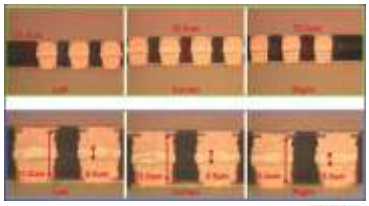


HAFC Key Specifications (C2S or C2W)

Process Requirements	Specification HAFC
Accuracy	± 3μm (3σ)
Thin die handling Die thickness	≥ 30 um
UPH	4500
Die Size	0.5 – 38.0mm
Substrate Size	310x160mm
Wafer Size	330mm
Maximum Force	150N
Yield and Metrology	Die crack detection Post bond overlay IR Align NCF

Risk mitigation for fine pitch Cu pillar assembly

Chip to Substrate Bonder



30um pitch – C2W HAFC

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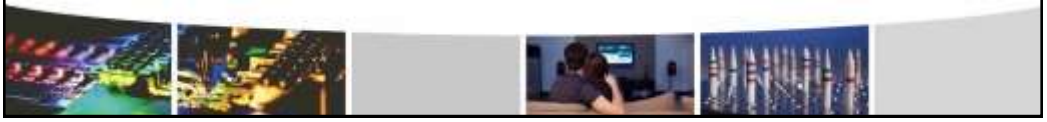
21

C2W FOWLP Die Placement

Kulicke & Soffa



APAMA C2W for FOWLP

- Dual head placement
- Face-down and Face-up die placement
- Global Alignment Capability

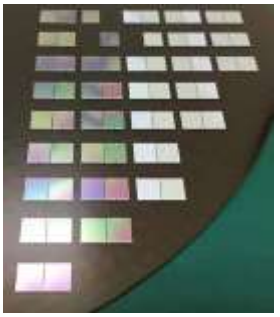
APAMA Platform Flexibility - FOWLP

- Demonstrated capability for C2W for FOWLP
  - Market requirement for both face up and face down die placement with higher accuracy
  - eWLB process face down (Infineon process)
  - TSMC InFO (and others) face up
  - 4500 UPH possible (linked to accuracy)
- Tools in evaluation with multiple Taiwan customers

Face-up FOWLP Demonstration

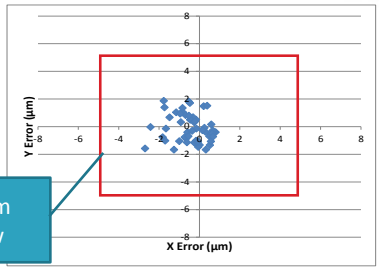
Wafer Info:

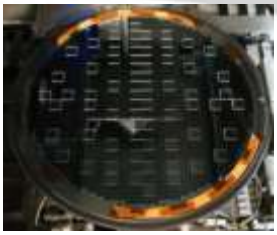
- Wafer type: glass
- Wafer size: 300mm
- Wafer thickness: 700mm
- Die spacing: 250um



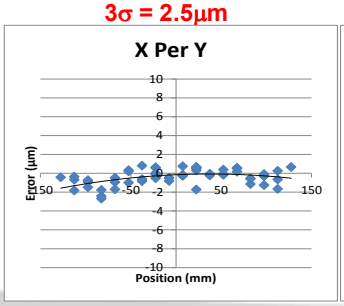
Placement of Glass Die on Glass Wafer

- Validation of global alignment accuracy
- 15 x 15mm glass die
- 55 die placed over 255mm diameter

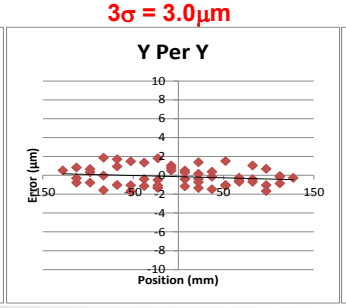




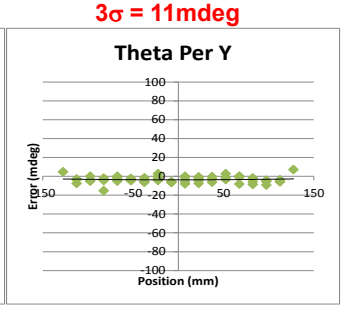
3σ = 2.5µm



3σ = 3.0µm



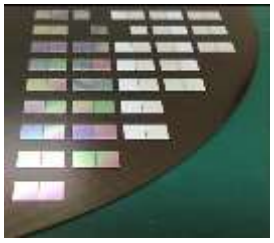
3σ = 11mdeg



C2W FOWLP Key Specifications

Process Requirements	Specification FOWLP
Accuracy	± 3-5µm (3σ)
Thin die handling Die thickness	≥ 30 um
UPH	4500
Die Size	0.5 – 38.0mm
Die Placement	Face Up or Face Down
Wafer Size	330mm
Maximum Force	150N
Bondhead Temp	Max: 150C
Chuck Temp	150-200C
Yield and Metrology	Die crack detection Post bond overlay IR Align NCF

Chip to Wafer Bonder



Summary

- K&S has developed the next generation thermocompression bonder to enable cost-effective, high performance packaging
- High accuracy inherent in the equipment design enables use of the equipment for HAFC and FOWLP processes
- Equipment with the flexibility for field conversion reduces capex risk
- HAFC demonstrated for mass reflow of 30mm pitch Cu pillars
- Accurate FOWLP die placement is possible with APAMA C2W system
  - Global alignment capability
  - Face up or Face down defined by recipe

APAMA™

MORE THAN BONDING

Advanced Packaging with Adaptive Machine Analytics

IEEE CPMT SCV - 25 Feb 2016 27