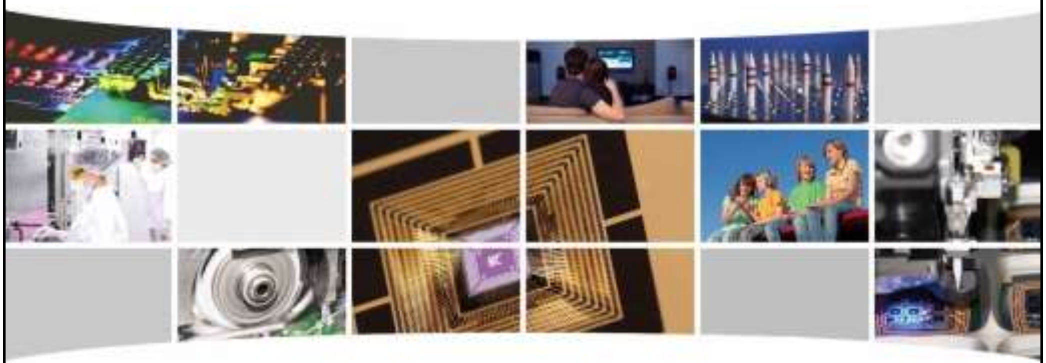


Kulicke & Soffa

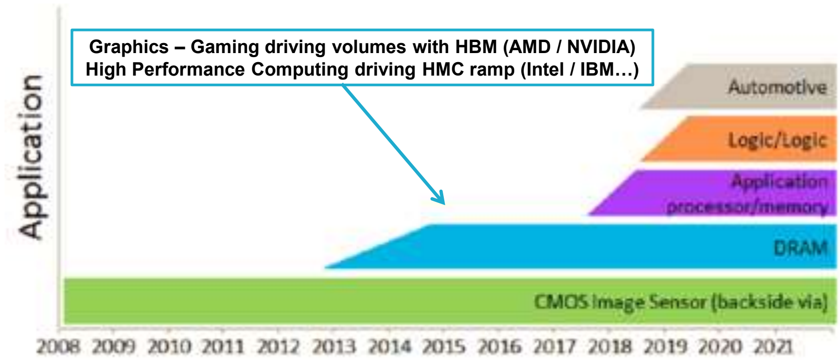
Flexible Manufacturing Platform for High Volume TCB and High Density FOWLP

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

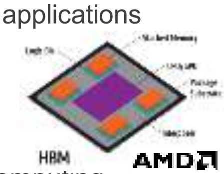


Source: TechSearch International, Inc.

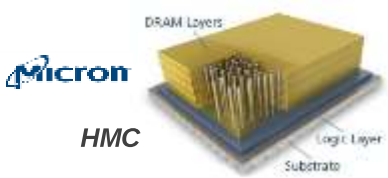
- **Image sensors with backside vias from Toshiba in January 2008, Sony CMOS image sensors + logic**
- **Tezzaron DRAM in 2013, Micron HMC, SK Hynix HBM, Samsung DIMM in 2015**
- **Logic on logic 2019 at the earliest**
- **Automotive (image sensor + logic) for safety reasons**

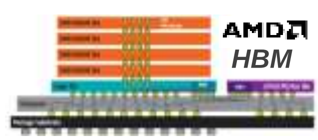
Packages Using Stacked Die

- 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





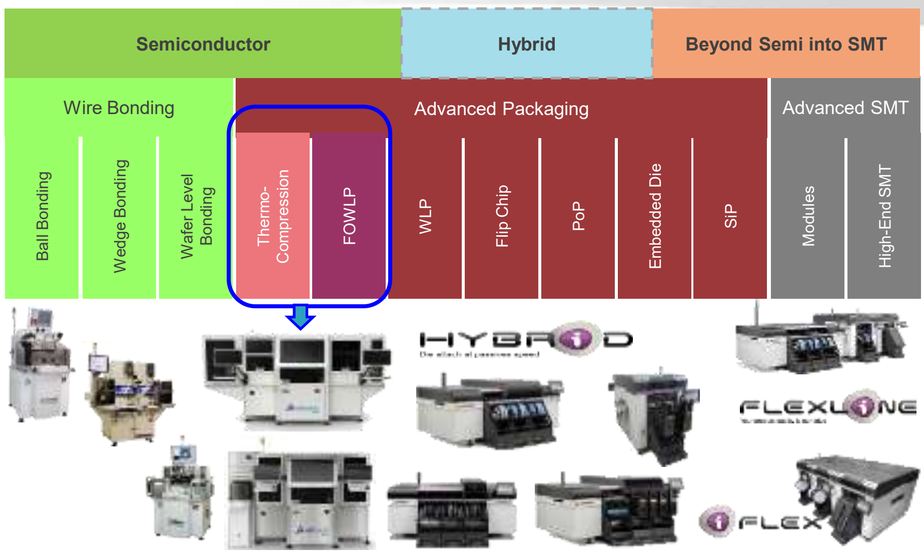
FOWLP Revenue Forecast

(source Yole Developpement)

FO WLP MARKET REVENUE FORECAST UPDATED 09/2015

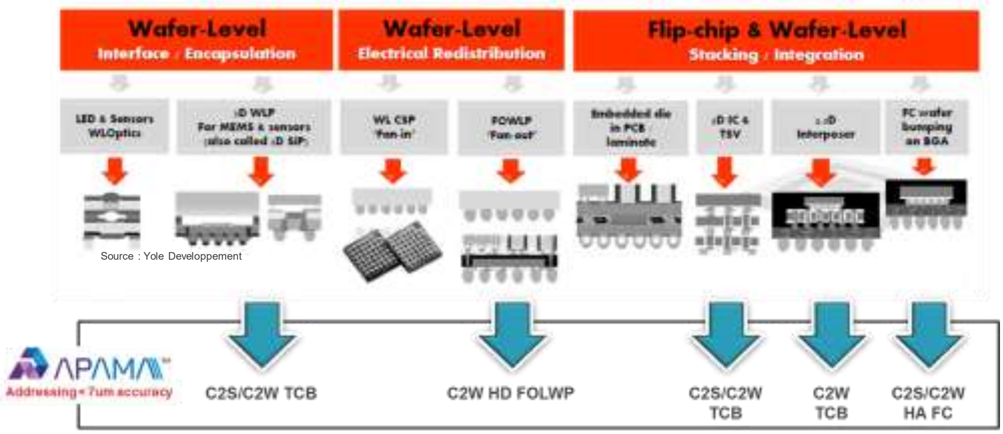
- TSMC info: entry of Apple A10 APE on iPhone7, 7+ and newer from 2016!
- Previous 2014-2020 CAGR was rated at 25%, while new 2014-2020 CAGR is estimated at 55%!
- After the jump, further 2016-2020 CAGR estimated at 32%
- Market estimated to exceed 2B$ by 2020

K&S Semiconductor Assembly Equipment



K&S Offers the Full Range of Semiconductor Assembly Equipment

APAMA Advanced Packaging Platforms



APAMA^{TM} Thermocompression Bonders

APAMA C2S TC Bonder

APAMA C2W TC Bonder

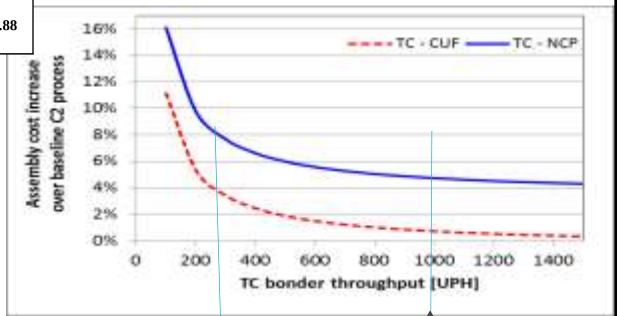
- High Accuracy design of the APAMA TCB platforms enable high capability in adjacent markets
- Improved accuracy over existing die placement solutions
- C2S and C2W platforms can be adapted for High Accuracy Flip Chip die placement (HAFC)
- C2W platform can be adapted to FOWLP die placement
  - FOWLP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

The Cost of TCB is Competitive at High UPH



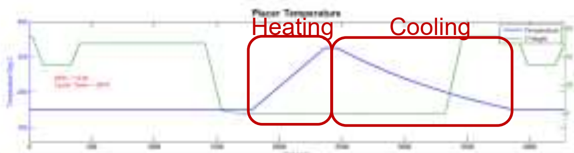
Today's TC Bonders Running in Production

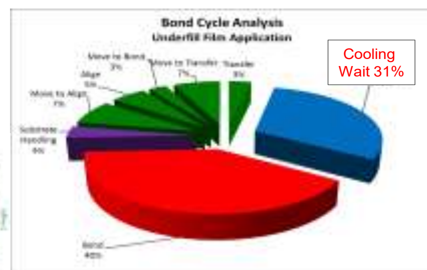
Small cost difference at 1000 UPH

- 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

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%





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
Pre-applied Underfill	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
No Pre-applied Underfill	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

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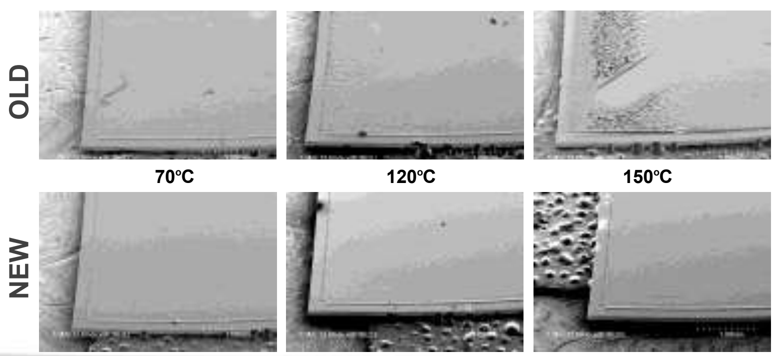
Improving NCF Throughput

- 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



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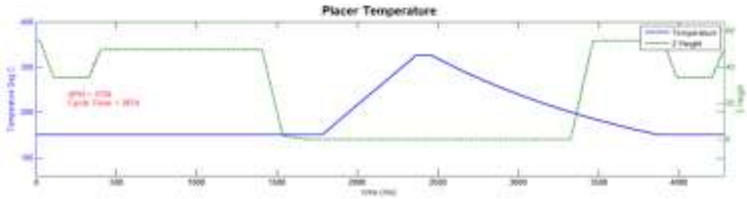
UPH NCF Hot Transfer Process

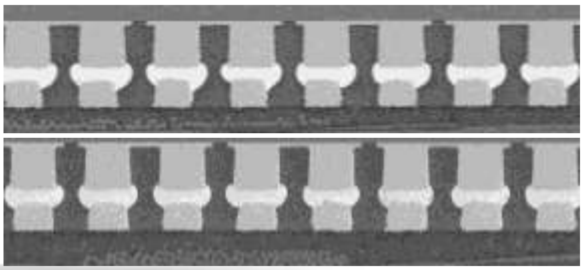
- Process without intermediate dwells achieves a UPH over 1700
- UPH is improved by 500 over the same process with an 80ºC transfer temperature
- Assumes 80 die/strip (10 sites x 8 die stack)

Hot transfer
150ºC

UPH: 1726
Cycle time: 3.9 sec

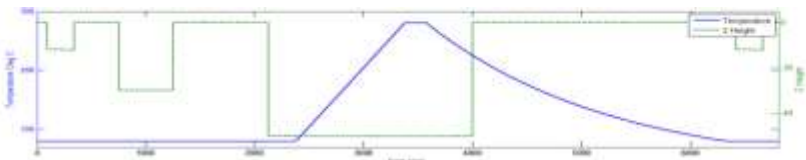


High speed NCF with excellent void performance and metallurgy

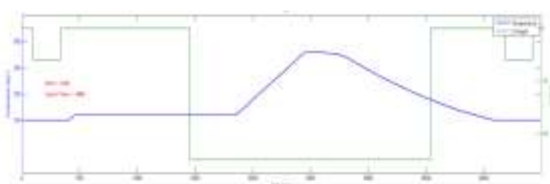


Substrate Fluxing for TC-CUF

- 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



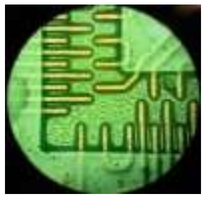
- Substrate fluxing is a fast process enabling a breakthrough for TCB
  - Without die flux dip the temperature excursion of bond head is limited to ~120ºC
  - Demonstrated a process with as low as 4.8 sec cycle per unit equaling a UPH of >1500
  - Potential to exceed 2500 UPH with higher temperature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



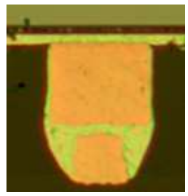
Substrate Fluxing UPH Improvement

- 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



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APAMA FACTS

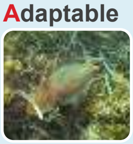
Mitigate Uncertainty of Technology Shifts & Protect Your Investments

Flexible

Highly Configurable Core Design

- TCB C2S
- TCB C2W
- HA FC
- FOWLP
- HA DA

Adaptable



Adapt to Your Transforming Environment

- FOUNDRY
- OSAT
- IDM
- R&D

Capable

Quality and Output Performance

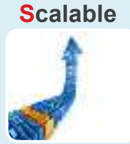
- Best UPH @ High Accuracy
- Best in Class process monitors & Integrated Metrology
- Best cost performance ratio

Transformable

An Evolutionary Core Machine that Protects Customer Investments

- TCB to FOWLP to HAFC
- Risk free solution
- Time to MFG

Scalable



K&S Global Infrastructure with Coverage for Sales/ Service/ MFG

- Repair/ refurbishment & warranty support
- Global support presence
- Supply ramp capacity

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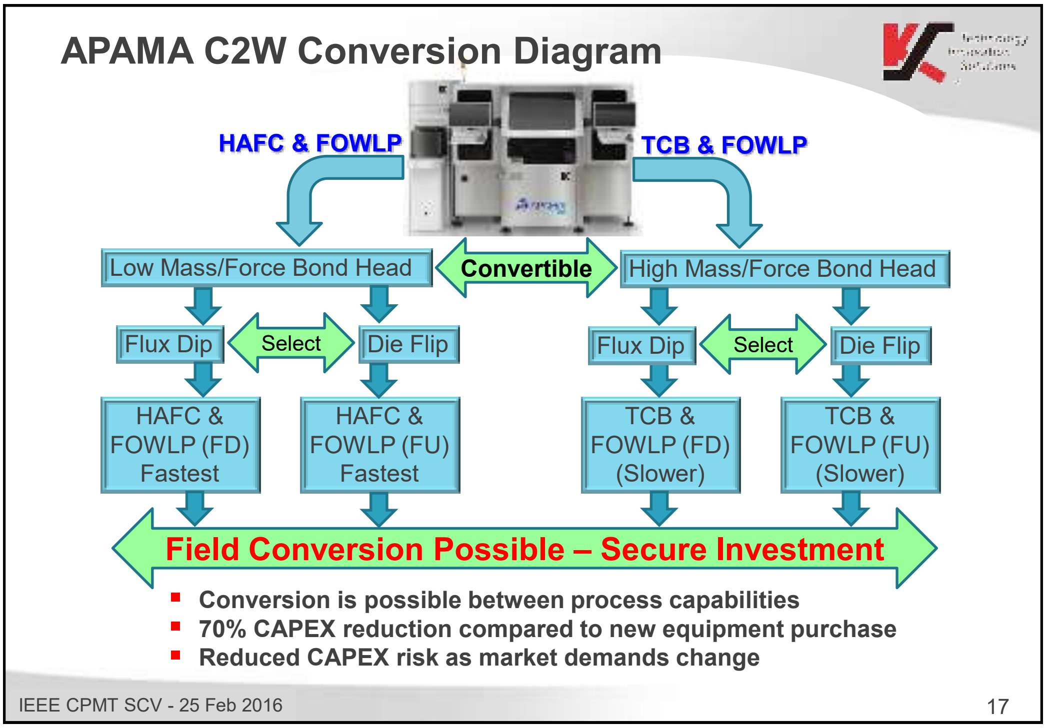
APAMA C2W Conversion Diagram
HAFC & FOWLP
TCB & FOWLP
Low Mass/Force Bond Head
Convertible
High Mass/Force Bond Head
Flux Dip
Select
Die Flip
Flux Dip
Select
Die Flip
HAFC & FOWLP (FD) Fastest
HAFC & FOWLP (FU) Fastest
TCB & FOWLP (FD) (Slower)
TCB & FOWLP (FU) (Slower)
Field Conversion Possible – Secure Investment
Conversion is possible between process capabilities
70% CAPEX reduction compared to new equipment purchase
Reduced CAPEX risk as market demands change
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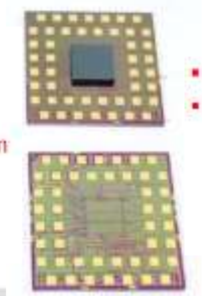
C2W HAFC Die Placement
Kulicke & Soffa

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

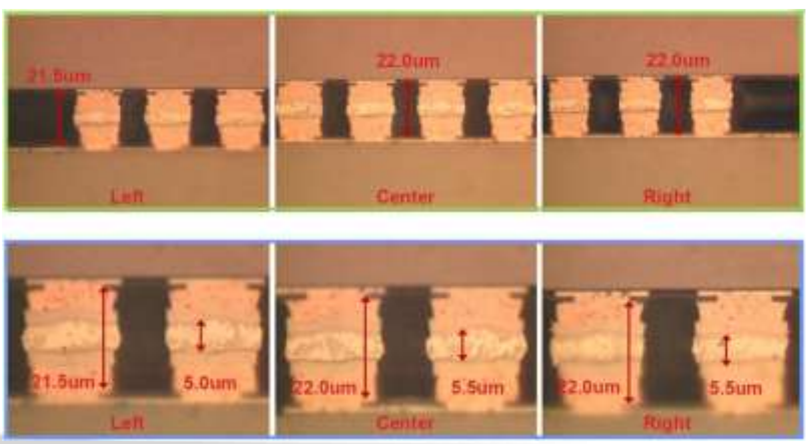
- Top Die
  - Length (X): 5.1mm
  - Width (Y): 5.1mm
  - Thickness (t): 700um
  - Bump height: 13um
  - Bump pitch: 30um
  - I/O: 3200



- 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

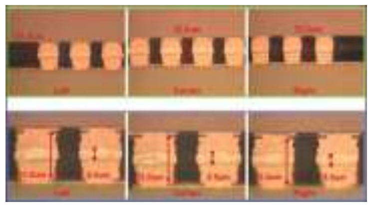
- Accurate placement of die enables self-alignment during the reflow process
- Example is silicon to silicon so CTE is matched
- Assembly onto laminate needs to account for CTE mismatch



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

Chip to Substrate Bonder



30um pitch – C2W HAFC

Risk mitigation for fine pitch Cu pillar assembly

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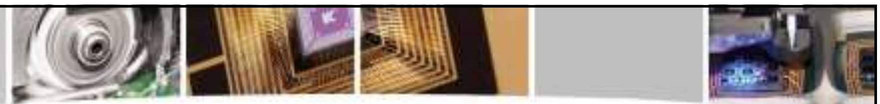

C2W FOWLP Die Placement

Kulicke & Soffa

Technology · Innovation · Solutions

APAMA C2W for FOWLP

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

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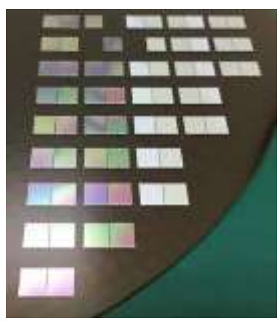
APAMA Platform Flexibility - FOWLP

- 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



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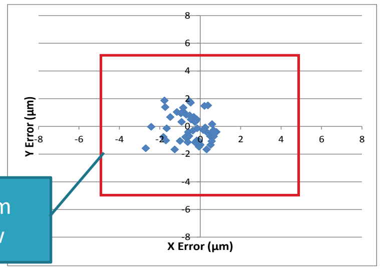
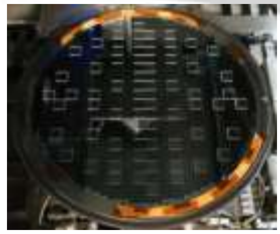
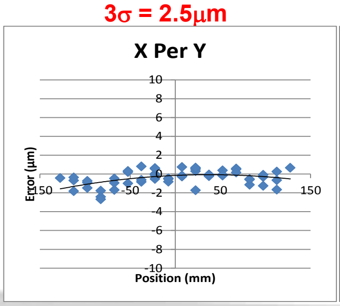
Placement of Glass Die on Glass Wafer

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

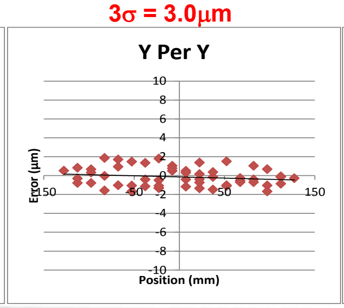




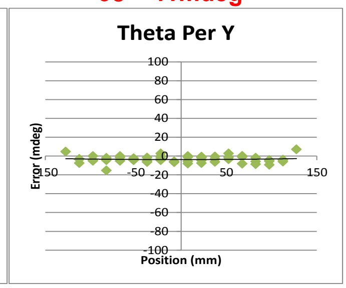
3σ = 2.5µm



3σ = 3.0µm



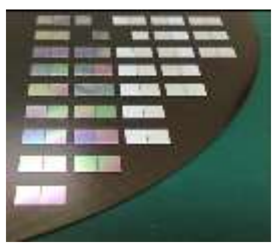
3σ = 11mdeg



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

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