Advancements in Vertical Wire Technology for Wire Bond Applications

Basil Milton
Director, Process Engineering, Ball Bonding
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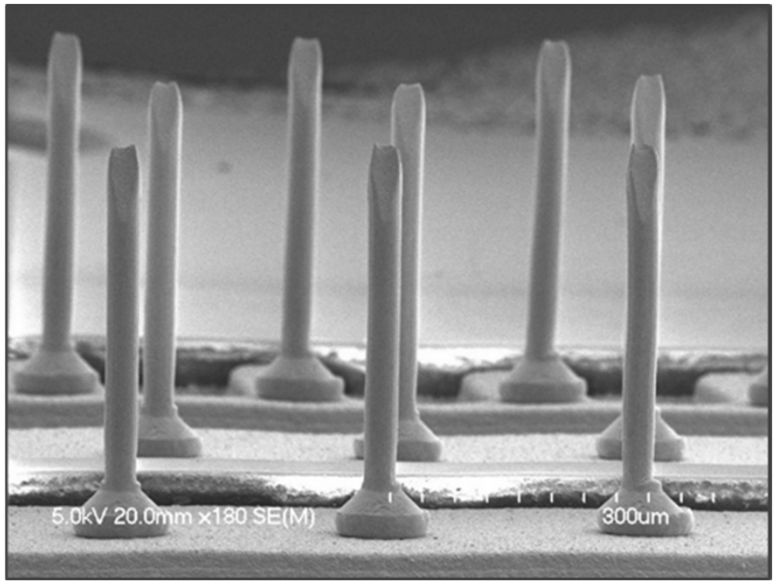
Kulicke & Soffa®

Agenda

- Introduction to Vertical Wire Technology
- Vertical Wire Applications
- ProVertical Loop™ Process
- Improved Wire Pitch Capability
- New Capillary Designs
- Vertical Wire Metrology
- Emerging Opportunities

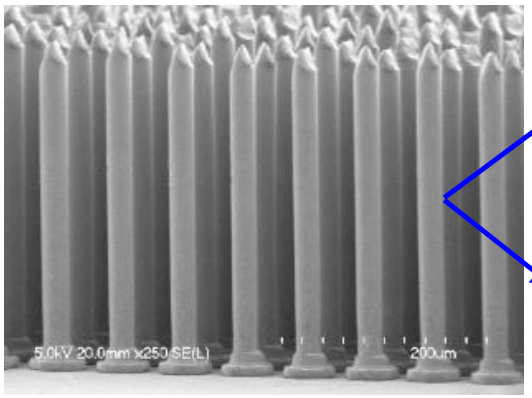
Vertical Wire Technology

- Vertical Wires are an emerging interconnect solution formed using a unique process on Ball Bonder equipment
- Vertical Wires are a lower cost alternative to through mold interconnects for both substrate as well as wafer level packages
- Although initially developed for interconnection applications, Vertical Wire was introduced in HVM for EMI shielding in SiP and RF packages

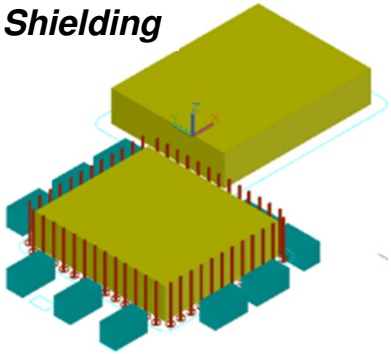


Vertical Wire Applications

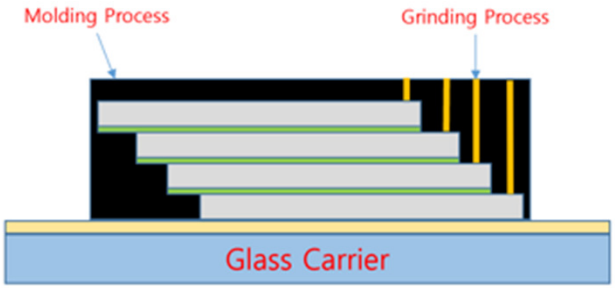
- Vertical Wire Technology provides
  - Increased I/O density and reduced package footprint
  - Flexible and simple solution for high performance shielding
  - Lower cost packaging alternative to through mold interconnects



EMI Shielding

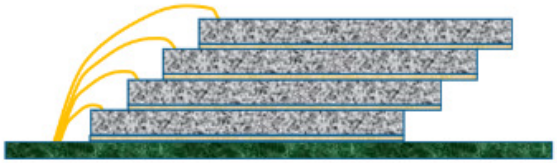


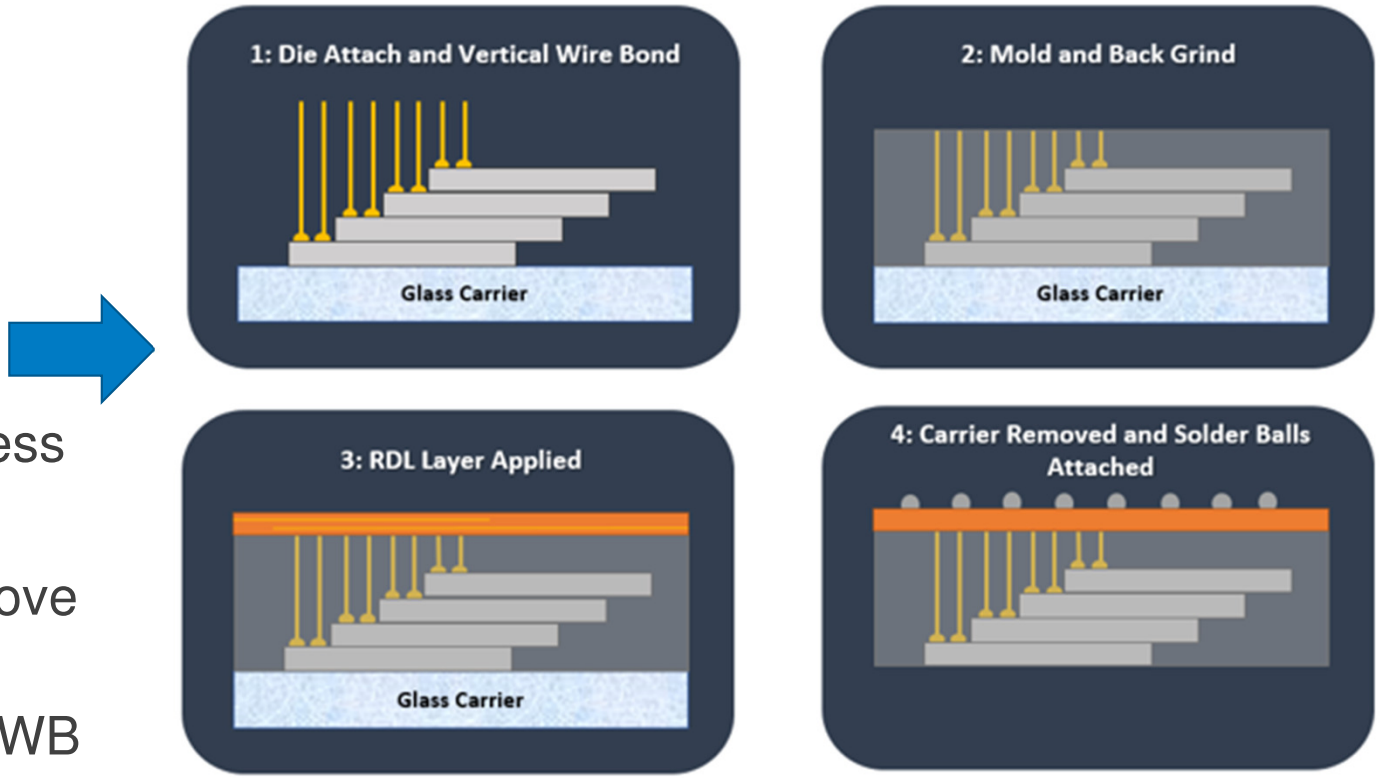
Through Mold Interconnect



Vertical Wire Wafer Level Packaging

Conventional Wire Bond



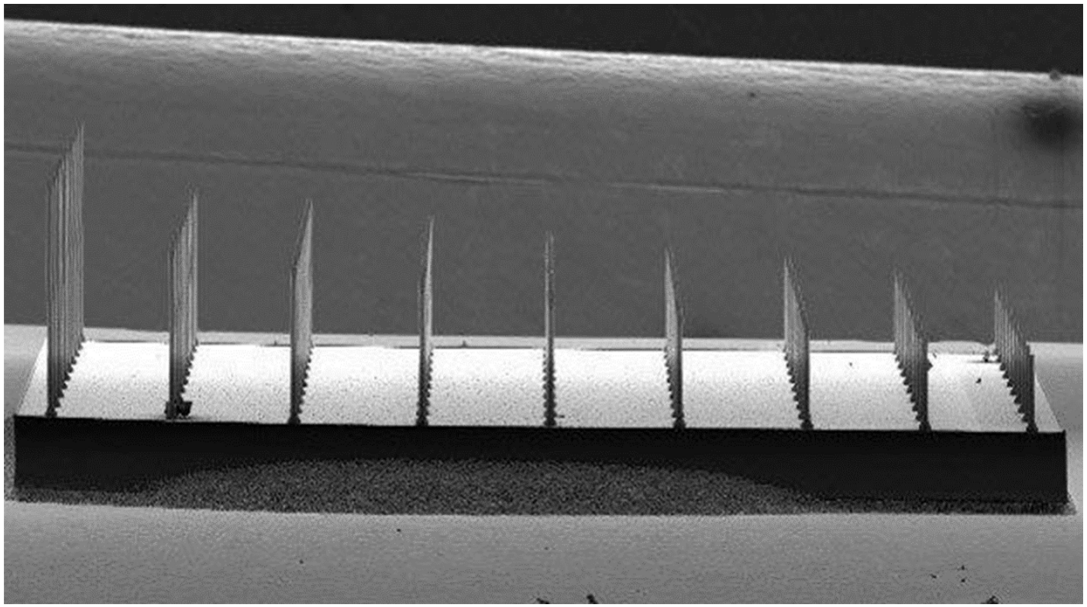


- ~30% reduction in thickness
- Higher I/O density
- Shorter wire lengths improve power efficiency by ~5%
- Higher cost compared to WB due to RDL process

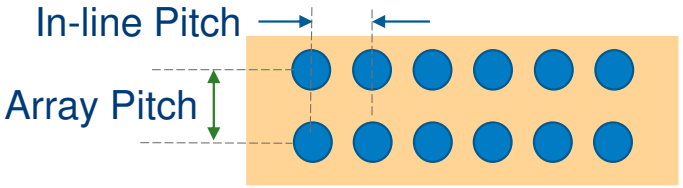
Source: Small Size, Big Impact: Unveiling the Latest Advances in Semiconductor Packaging and Miniaturization, SK Hynix, July 2023

1st Gen ProVertical Loop™ Capability Range

- Wire Types: Cu, PdCu, Ag, Au
- Wire Diameter: 15µm ~ 75µm
- Wire Height: 80µm ~ 1200µm
- XY Tip Repeatability: ± 10µm
- Min Wire Pitch: 40µm
- Min Array Pitch: 80µm

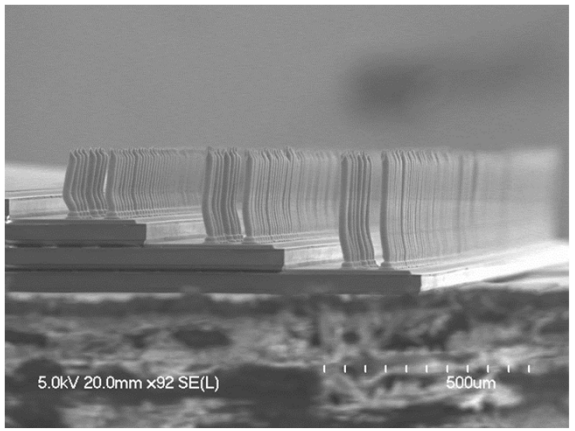


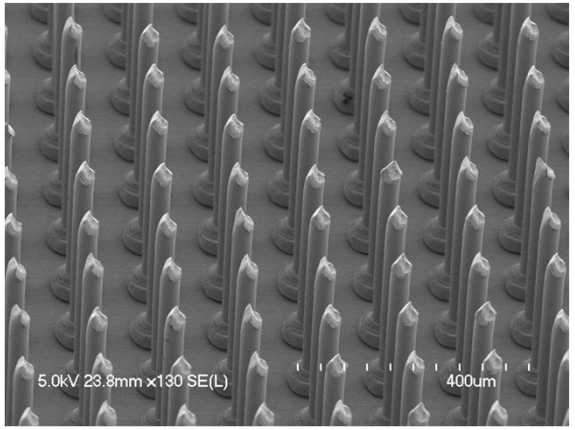
Top View of Wires



Vertical Wire Enhancements

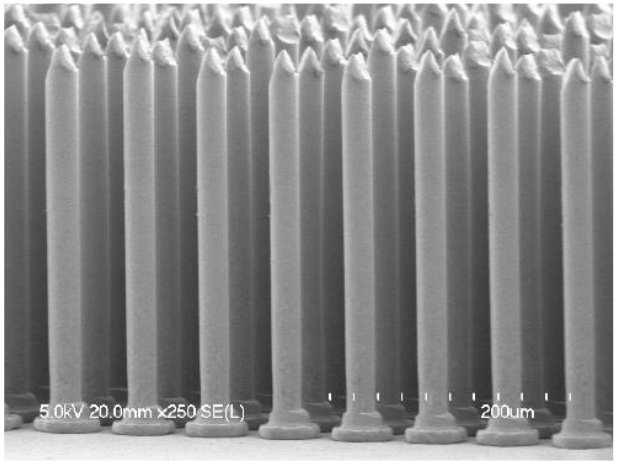
- Package Design Trends
  - Memory are trending towards taller die stack configurations with finer pad pitch and multi-rows to increase I/O density
  - SiP packages have shrinking die and reduced component spacing
- New Vertical Wire Solutions are required to:
  - Enable finer vertical wire pitch and array pitch for multi-row bonding
  - Allow for reduced component-to-component spacing
  - Improve wire straightness and repeatability





2nd Gen ProVertical Loop Plus™

- **ProVertical Loop Plus** is a new Vertical Wire process that uses a second set of wire clamps to improve wire pitch capability and enable reduce component-to-component spacing
- The new process delivers:
  - Improved wire straightness and tip accuracy
  - Reduced wire array pitch capability
  - Flexible selection of nicking locations



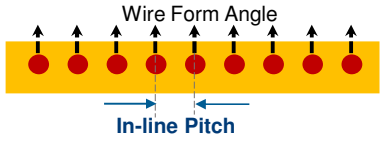
2nd Gen ProVertical Loop Plus™ Capability Range

- Wire Type : Au, Ag, Cu and PdCu wires
- Wire Diameter : 0.7 ~ 1.2 mils
- Wire Height : 160 ~ 550µm, taller wire under evaluation
- Wire Pitch : f (Cap dimension, wire diameter and wire height)
- Height Repeatability : ± 15 µm application dependent
- XY Tip Repeatability : ± 5 µm
- Software Version : 4-85 onwards

Wire Pitch Improvement

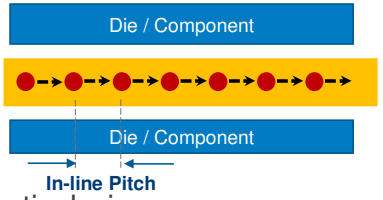
ProVertical Loop™

- Pitch = function of wire diameter, wire height, cap dimensions, wire form angle, wire sequence, die/component
  - Single row vertical wire and wire form angle is perpendicular to bonding sequence



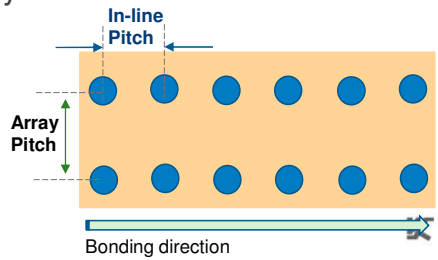
Finest Pitch

  - Single row vertical wire and wire form angle is in-line with bonding sequence



Larger Pitch

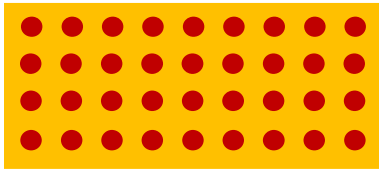
  - Arrayed vertical wires



Largest Pitch

ProVertical Loop Plus™

- Pitch = function of wire diameter, wire height and cap dimensions, ~~wire form angle, wire sequence, die/component~~.
- Array pitch = In-line pitch, finest pitch for all scenarios



- Reduced Package Footprint
- Improved Package Performance
- Simplified Design Rules

Wire Pitch Capability for 18µm Wire Diameter

- Wire Pitch is a function of wire diameter, wire height, and Capillary Tip Diameter.
- Below table is minimum pitch per wire height for 0.7mil wire diameter

Wire Dia 0.7mil 18µm		Wire In-Line Pitch [µm]													
		40	45	50	55	60	65	70	80	90	100	120	140	160	180
Wire Ht [µm]	130														
	150														
	170														
	200														
	230														
	250														
	270														
	300														
	350														
	400														
	450														
	500														
	550														
	600														
	700														
	800														
	850														

Green box = capable
Red box = not capable

Note: wire pitch capability is for inline and array pitch

Wire Pitch Capability for 30µm Wire Diameter

- Wire Pitch is a function of wire diameter, wire height, and Capillary Tip Diameter.
- Below table is minimum pitch per wire height for 1.2mil wire diameter

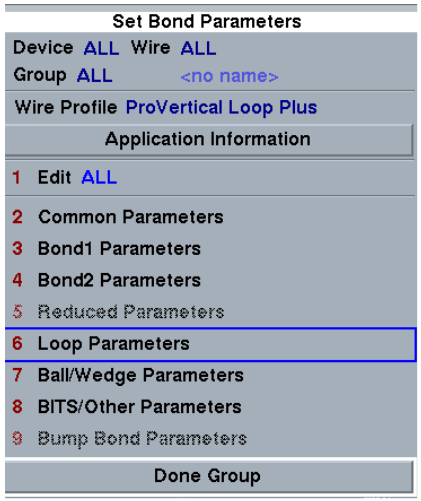
Wire Dia 1.2mil 30µm	Wire In-Line Pitch [µm]																
Wire Ht [µm]	50	55	60	65	70	80	90	100	110	120	135	145	150	155	165	170	180
140																	
170																	
200																	
250																	
300																	
350																	
400																	
450																	
500																	
550																	
600																	
650																	
700																	
750																	
800																	
850																	
900																	
950																	
1000																	

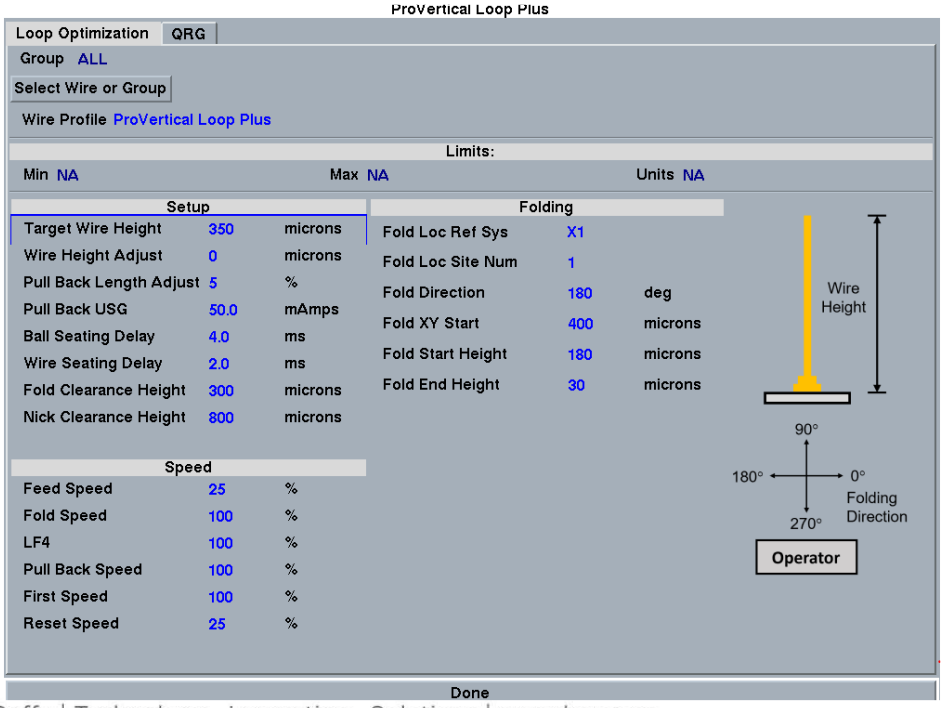
Green box = capable
Red box = not capable

Note: wire pitch capability is for inline and array pitch

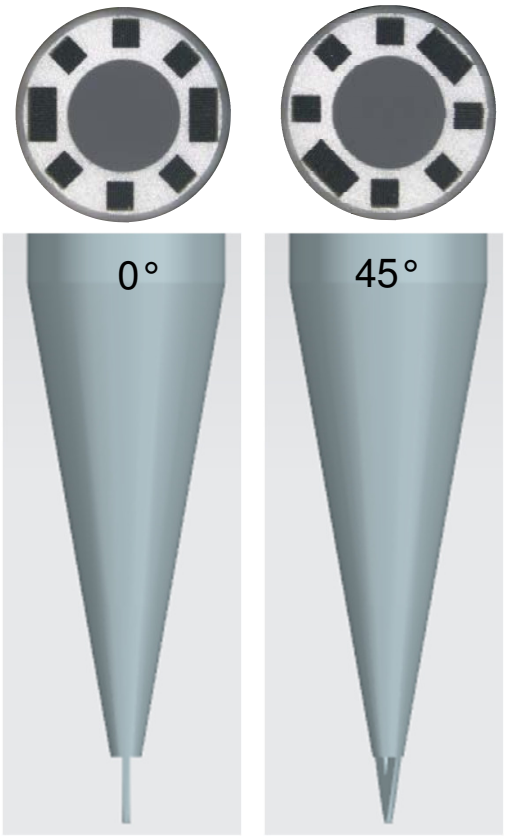
Response-based Process Optimization

- ProVertical Loop™ & ProVertical Loop Plus™ use intuitive response-based parameters for quick and easy process optimization
- Most processes are optimized within a day or two



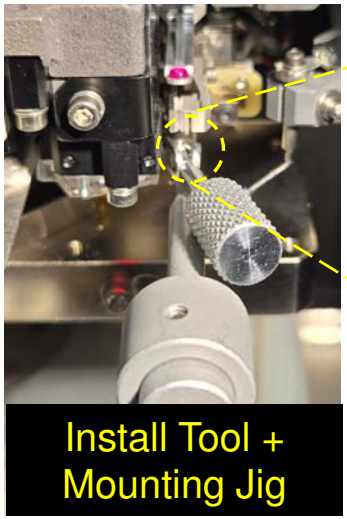


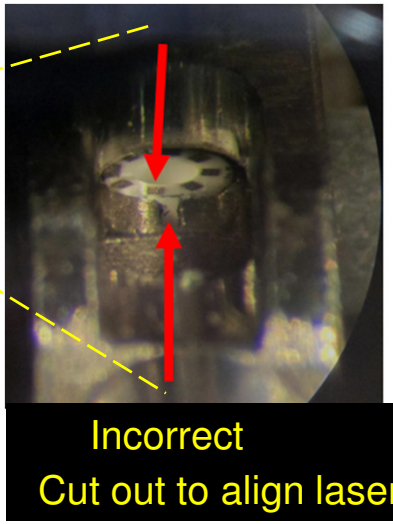
Improved Pitch with New Capillary Designs

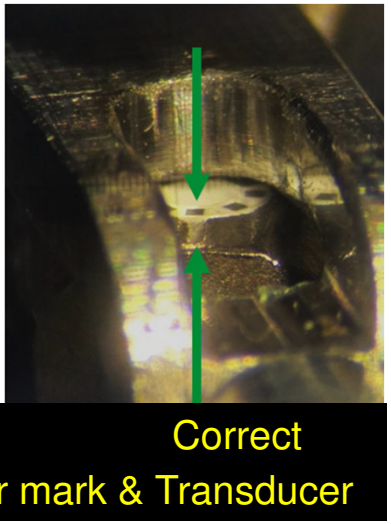


- 45° install allows bonding on all quadrants – 500µm ht, 56µm pitch
- Large laser mark on cap indicates side cuts. Small mark at 45°
- Cap Install Tool for easy mounting at desired angle
- Cut-out on Jig to ensure cap is installed easily and accurately


Install Tool

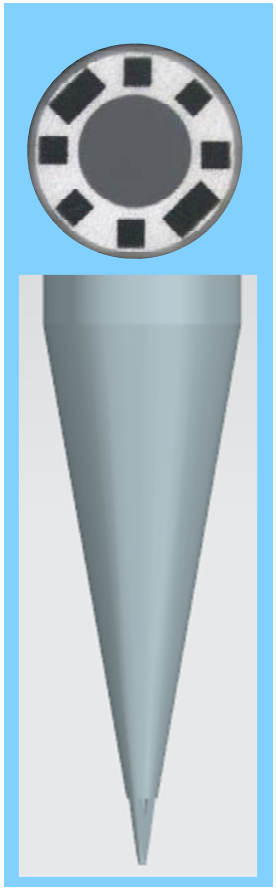

Install Tool + Mounting Jig


Incorrect


Correct

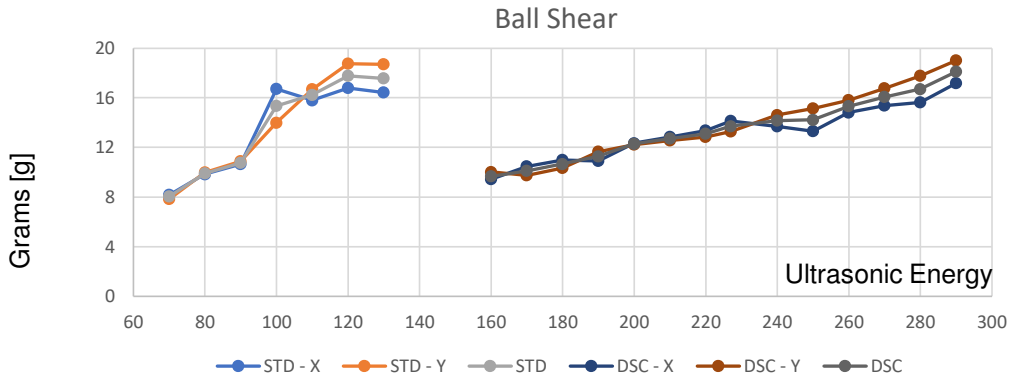
Cut out to align laser mark & Transducer

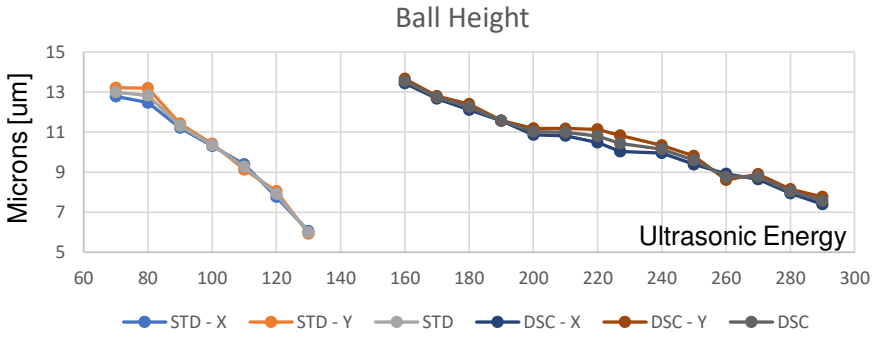
Dual Side Cut Capillary Process Test Results

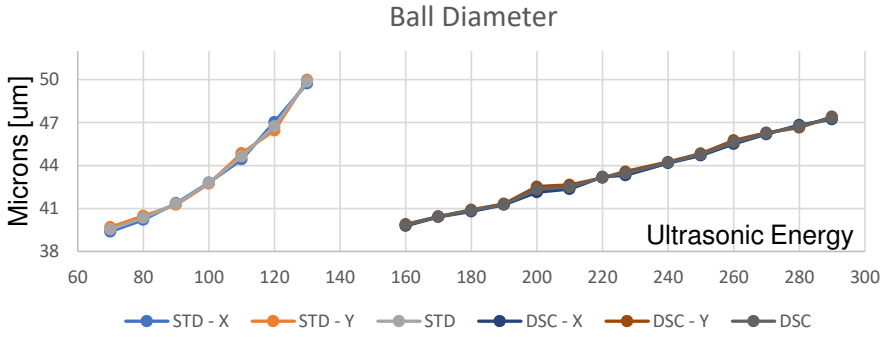


Test Orientation

Capillary Dimensions		
Parameter	Value	Units
T	60	µm
H	25	µm
CD	31	µm
OR	8	µm
FA	8	deg
ICA	70	deg
CA	20	deg
Cut Ht	530	µm
Cut W	32	µm



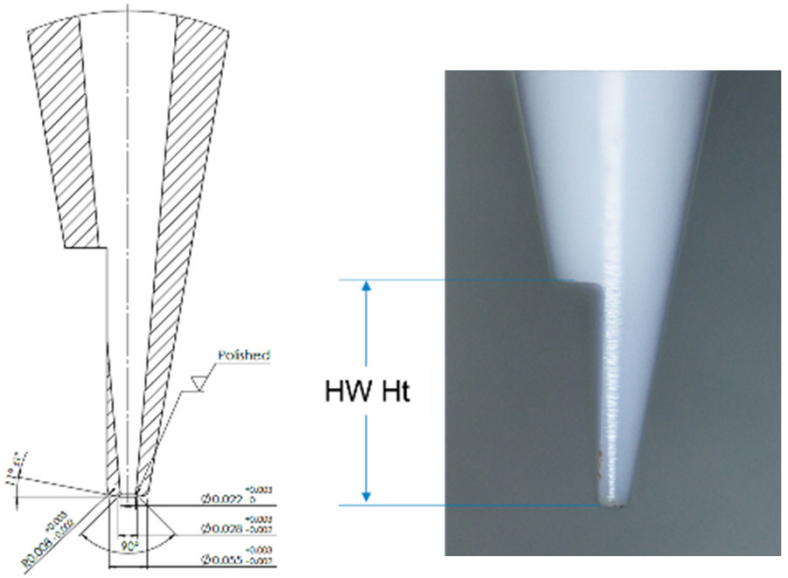




- Process window for DSC Cap shifted higher as it requires more USG for equivalent performance
- DSC Cap stays above the 5.5 g/mil^2 threshold for the majority of the bonding window

Improved Pitch with New Capillary Designs

- *Single Side Cut Capillary* can further improve wire pitch capability
- Applicable to both ProVertical Loop and ProVertical Loop Plus processes



Note: Cap selection is application dependent. When applicable, the Dual Side Cut Capillary (Slide 11) is recommended over Single Side Cut Capillary due to its symmetric design.

Improved Pitch with Single Side Cut Cap

18um Wire Dia

Wire Dia 0.7mil 18µm	Wire In-Line Pitch [µm]												
Wire Ht [µm]	35	40	42	45	50	60	70	80	90	100	110	120	130
130													
150													
170													
200													
230													
250													
270													
300													
350													
400													
450													
500													
550													
600													
700													
800													
850													

30um Wire Dia

Wire Dia 1.2 30µm	Wire In-Line Pitch [µm]											
Wire Ht [µm]	60	65	70	75	80	100	110	130	150	170	190	210	230
140													
170													
200													
250													
300													
350													
400													
450													
550													
600													
650													
700													
750													
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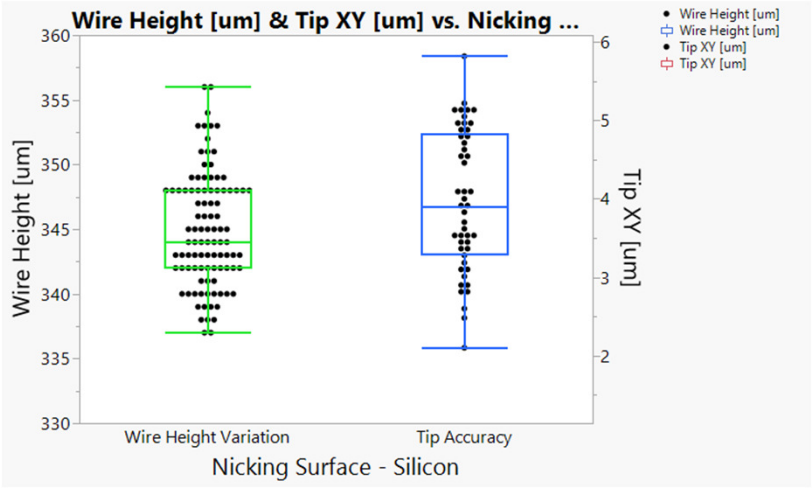
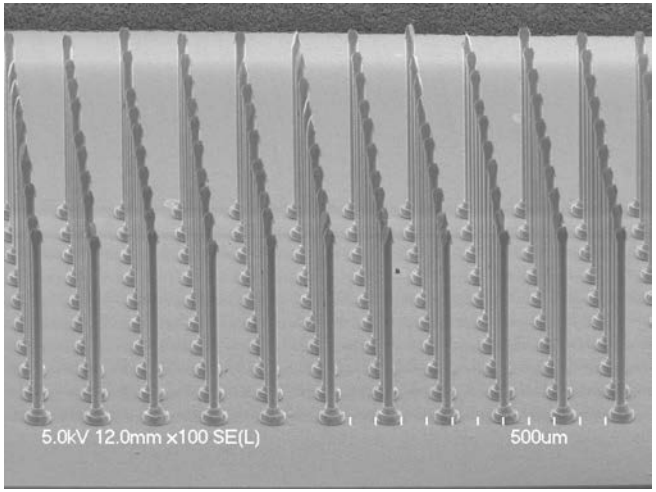
850													
900													
950													

- Single Side Cut Capillary provides significant improvement in both in-line wire pitch and wire height capabilities

Application Example - 0.8 mil Au



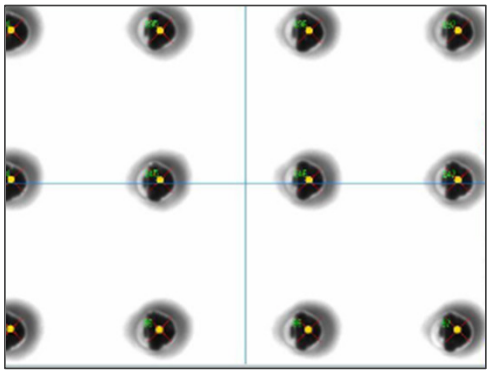


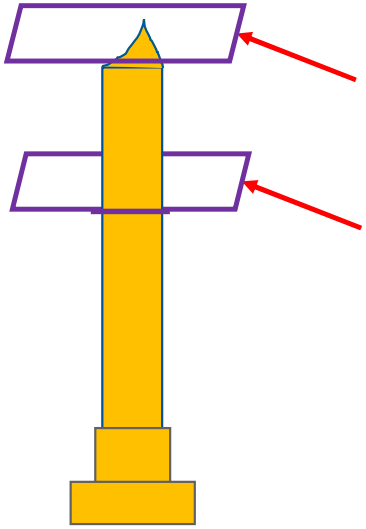
	Wire Ht [µm]	Tip XY [µm]
Avg.	344.96	3.95
Max.	356.00	5.82
Min.	337.00	2.10
Range	19.00	3.72
StdeV	4.39	3.95

Metrology: Vertical Wire Tip & Height Inspection

- On-bonder Vertical Wire Inspection features ensure yield by verifying XY tip location repeatability
- Vertical Wire XY location is measured optically relative to 1st bond
- Vertical Wire height is measured by contact at the wire tip

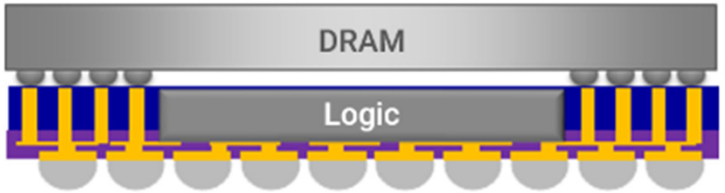
Automatic Optical Inspection





Emerging Opportunities

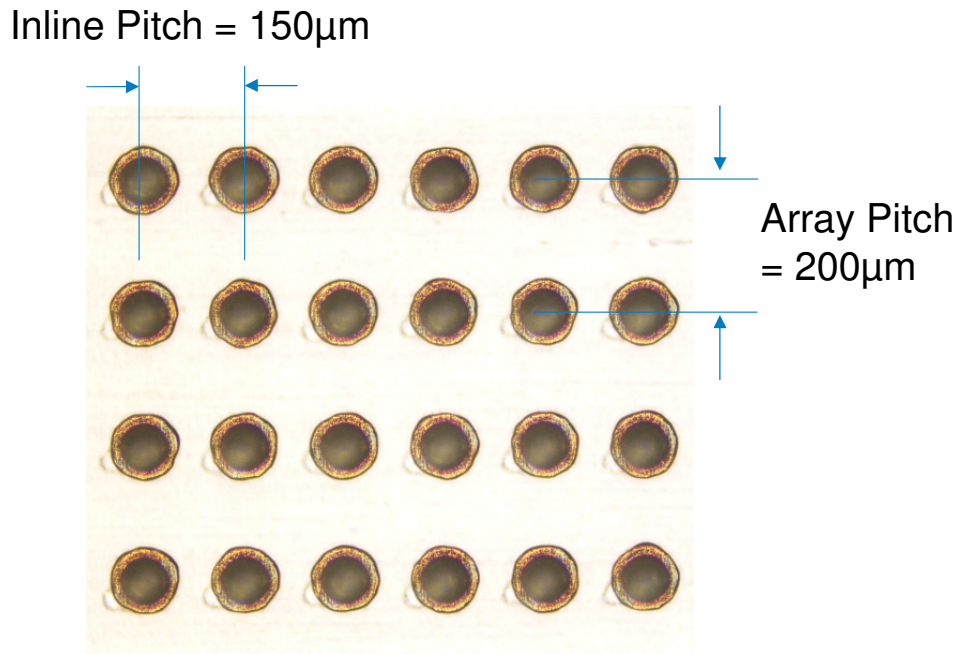
- Other opportunities for using Vertical Wire in packaging under evaluation
  - Vertical Wire as lower cost alternative to Cu Pillar
  - Replace Cu posts for through-mold vertical interconnections in Fan-Out Package on Package (FO PoP)
  - Expanded use of Vertical Wires for shielding applications



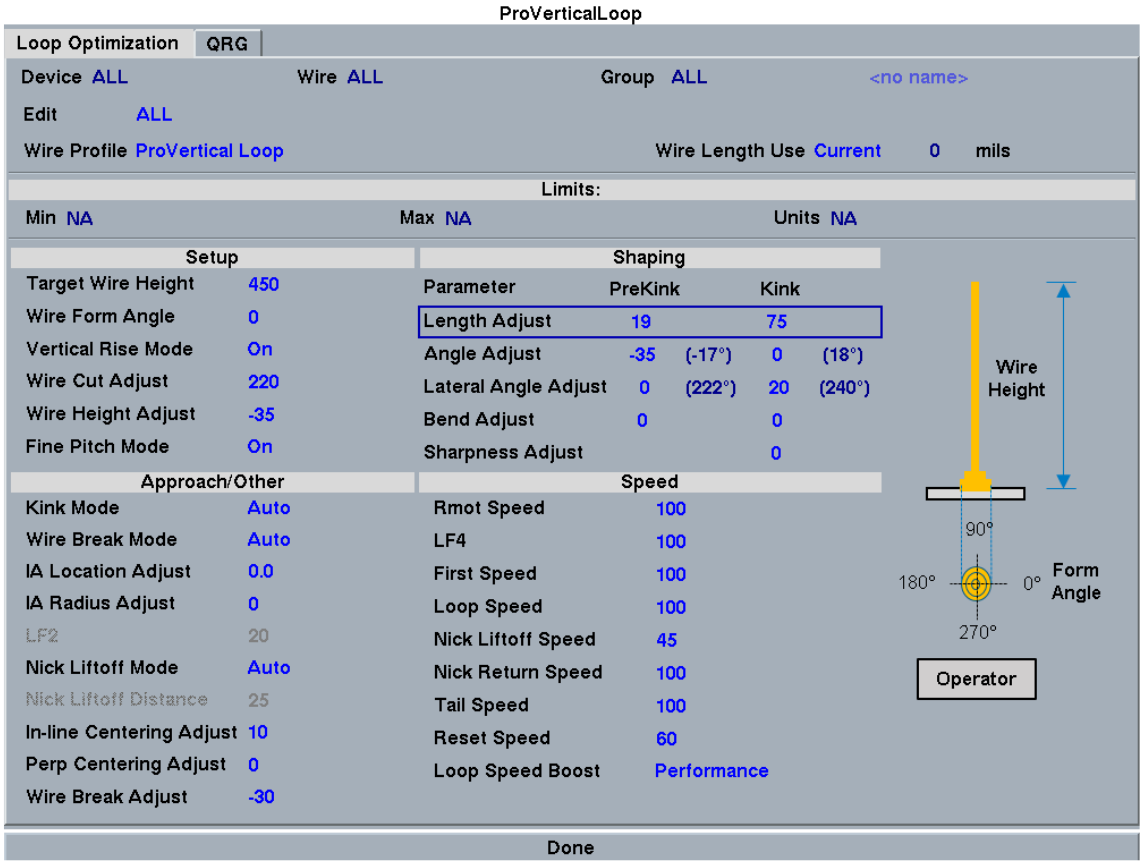
Vertical Wire Capability – 50um Wire Diameter

- Target Wire Height : 450µm
- Inline bond pitch : 150µm
- Array pitch : 200µm
- Target Ball Diameter : 100µm
- Target Ball Height : 20-35% of ball diameter
- Ball Bonder : RAPID Pro

- Wire : PdCu 50µm Heraeus PdSoft
- Capillary : PROTOTYPE05211
  H63 CD75 T153 OR15 FA11
- Bond temperature : 50/150/50℃

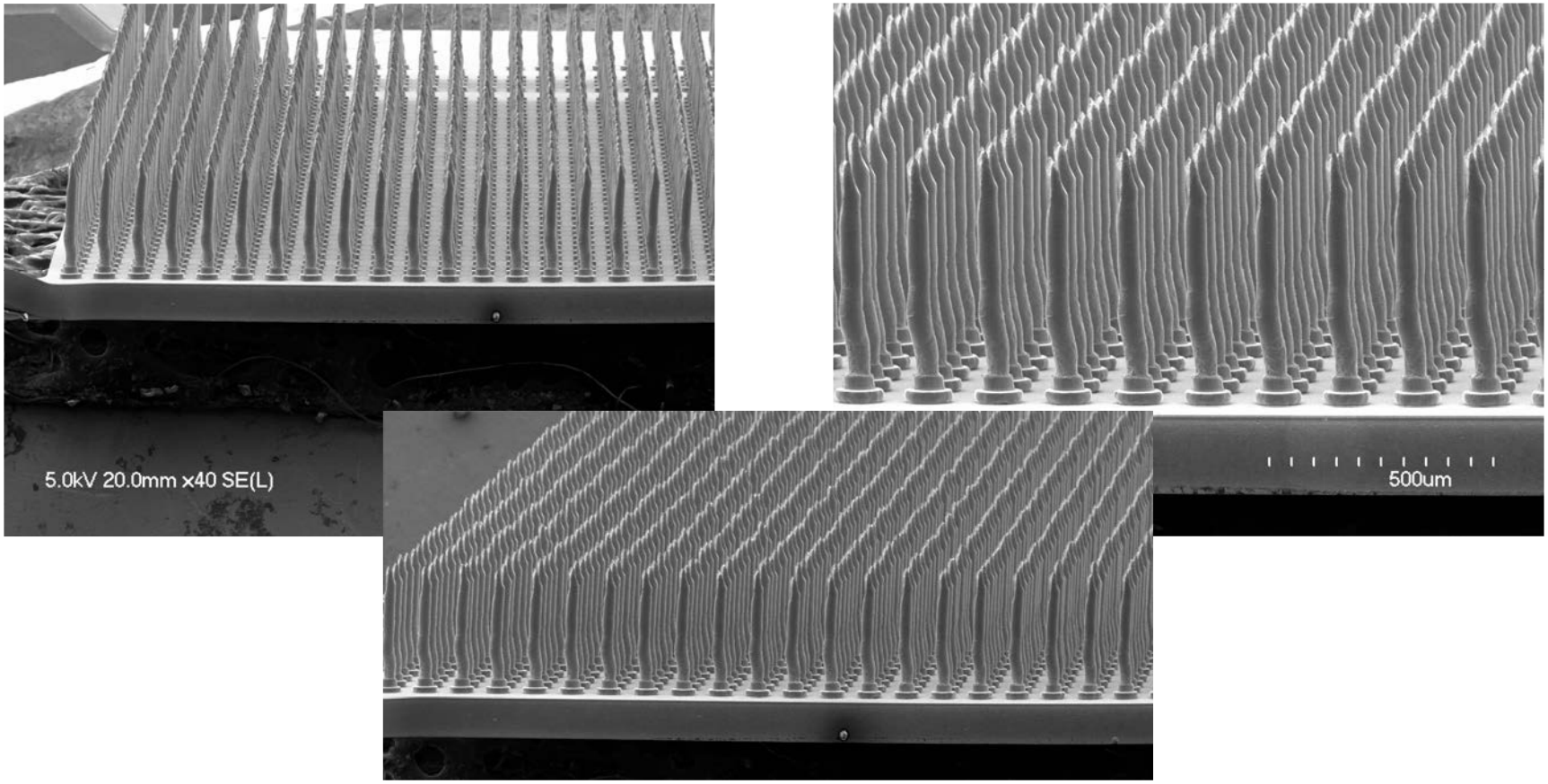


ProVertical Wire - Bond Parameter Settings



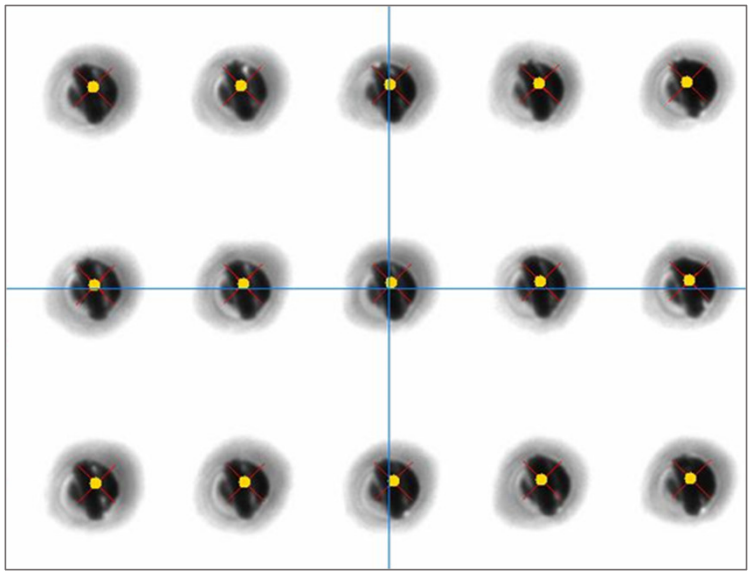
- Program was taught on blank K&S test device with 320 wires
- Bonding time was collected with ~8.5 wires per second

SEM Images



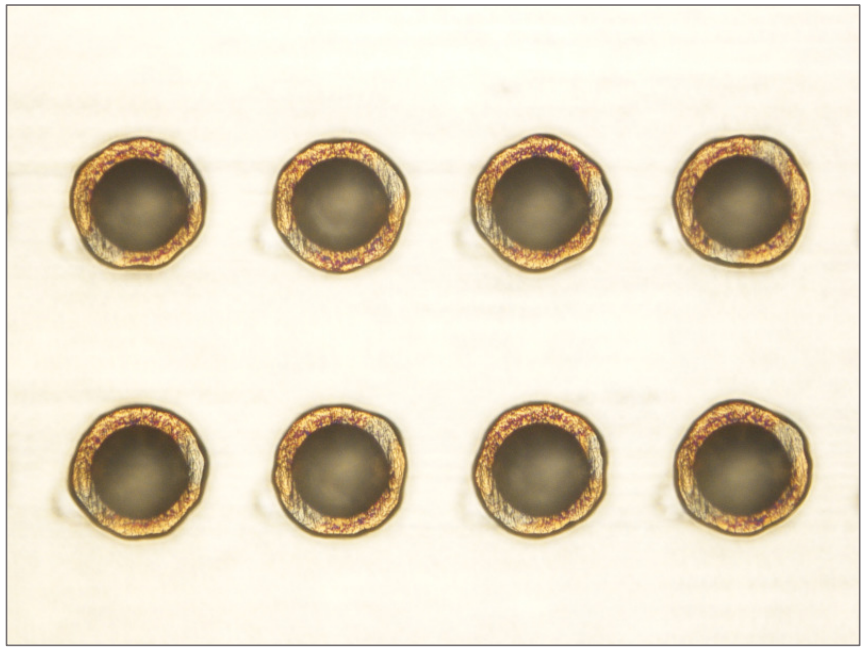
Wire Tip Placement and Height

	Wire tipX (µm)	Wire tipY (µm)	Tip XY (µm)	Wire Height (µm)
Average	**0.9**	**-3.2**	**-1.1**	**455.9**
Stdev	1.9	1.6	1.5	8.7
Min (µm)	-3.5	-5.7	-4.3	440.0
Max	3.8	0.3	1.6	469.7
Range	7.3	6.0	5.9	29.7
1	2.9	-2.2	0.35	450.6
2	2.5	-3.5	-0.5	468.4
3	2.6	-0.9	0.85	447.9
4	-1.6	-3.5	-2.55	447.6
5	1	-4.1	-1.55	446.9
9	-2.2	-4.4	-3.3	447.5
10	1.6	-5.1	-1.75	448
12	-1.5	-4.7	-3.1	440
17	-1.9	-3.5	-2.7	460
18	2.9	-2.9	0	458.4
19	1.6	-3.8	-1.1	467.9
20	2.2	-3.2	-0.5	445.9
24	-0.3	-2.9	-1.6	462.7
25	2.9	-3.2	-0.15	461.5
26	2.2	-2.2	0	469.6
31	0.3	-3.2	-1.45	460.8
38	0	-3.8	-1.9	461.5
39	1.6	-2.5	-0.45	466.3
40	-1.3	-5.4	-3.35	462.2



Bonded Ball Diameter and Height

	Ball X (µm)	Ball Y (µm)	Ball XY (µm)	Ball Height (µm)
Average	**103.4**	**100.7**	**102.1**	**24.2**
Stdev	1.2	1.3	1.0	0.8
Min	101.4	97.9	100.1	22.9
Max	106.9	103.6	105.1	25.8
Range	5.5	5.7	5.0	2.9
1	103	100.1	101.55	25.6
2	103.9	101.4	102.65	23.6
3	102.7	103.6	103.15	25.8
4	101.7	101	101.35	24.2
5	102.7	100.4	101.55	23.9
9	101.4	101	101.2	25.4
10	102.7	98.8	100.75	25.1
12	104	101	102.5	23.2
17	101.7	99.8	100.75	23.1
18	104	99.1	101.55	23
19	103.1	101.4	102.25	22.9
20	103.7	99.7	101.7	23.8
24	104	100.4	102.2	25.7
25	102.3	97.9	100.1	24.4
26	104.7	100	102.35	24.3
31	103.6	100.7	102.15	24.5
38	102.4	99.1	100.75	25.4
39	103.1	100.7	101.9	23.4
40	106.9	103.2	105.05	24



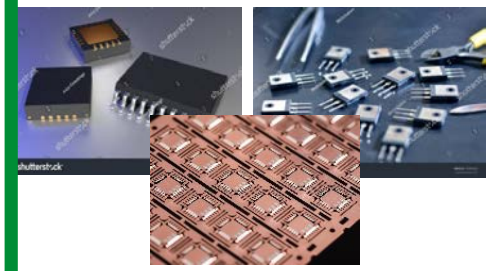
World's Leading Solutions for IC, Memory, LED and Wafer Level Packages

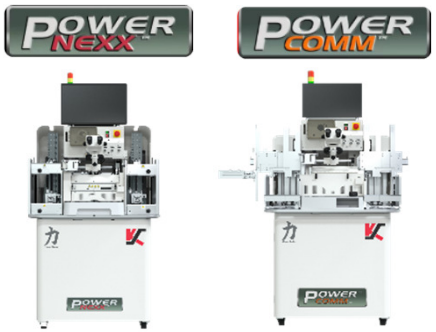
High Performance/Memory

Vertical Wire Bonding on Substrate

- Maximum yield and performance for high density and fine pitch packages
- Advanced Response Based Processes solve biggest packaging challenges with best CoO
- NEW Enhanced Memory Capability further improves UPH and looping performance –

Cost Performance



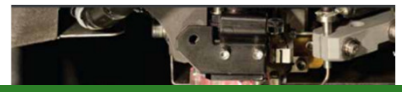


- Highest throughput and best CoO for QFN, discrete and low pin count packages
- NEW GCK PLUS Kit provides best Bare Cu leadframe solutions
- NEW auto recovery suite maximizes equipment productivity

LED

- Maximum throughput and MTBA for RGB and General Lighting LED packages
- NEW advanced LED bonding and looping capabilities optimized for highest yield and reliability

Wafer Level Bonding

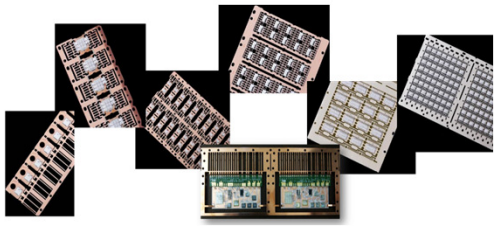


Vertical Wire Bonding on Wafer

- NEW ATP MEM Plus with Highest throughput for wire bonding and bumping on panel or wafer level packages
- Flexible solution - conventional or vertical wire bonding on up to 300mm wafer

World's Leading Solutions for Power Devices & Energy

Power Discrete



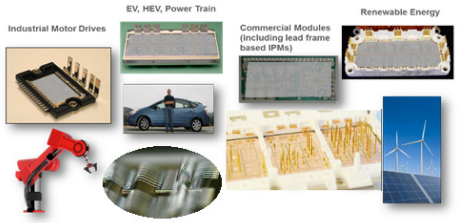
POWER-C PLUS

POWERFUSION

NEW

- NEW PowerC Plus includes expert solutions with the best COO
- High throughput
- Best reliability
- Fastest time to market

Power Hybrid



ASTERION

ASTERION PW

NEW

- NEW ProCu feature enables robust Cu wire bonding and cutting
- NEW Asterion-PW: the world's fastest and most precise ultrasonic Pin Welder
- NEW K&S MHS options available

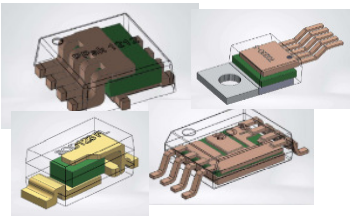
Alternative Energy

ASTERION EV

ASTERION SV

- Extended stroke bonders to reliably interconnect large format cylindrical batteries
- Largest install base in the world

Clip Attach



NEW

AVALINE

CLIP ATTACH LINE

- NEW Avaline system: Die Attach, Clip Attach and Vacuum Reflow Oven
- High placement accuracy
- High throughput
- Low solder voids

Questions?

Thank You!

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