WLCSP and Flip Chip Production Bumping using Electroless Ni/Au Plating and Wafer Level Solder Sphere Transfer Technologies

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Abstract
There are three main packaging technologies used by the semiconductor industry today to create solder bumps on wafers: paste printing, electroplating, or sphere dropping [1]. The choice between these technologies is highly influenced by the following criteria: the bump size & pitch requirements, cost, and overall yield. As the bumping industry evolves, many of the deficiencies and trade-offs associated with the three bumping technologies are no longer acceptable. As a consequence, a significant transition is occurring toward a fourth bumping alternative: Solder Sphere Placement [2]. This technique offers wide flexibility in bump size (40-760um), very high bump yields (>>99%) and low cost (sphere price dominated).

Keywords: Solder Bumping, Solder Sphere, Ball Placement, Sphere Transfer, FlipChip, WLCSP.

Introduction

Solder bumping is often separated into several different categories: flip chip bumping (FC), wafer level chip scale packaging (WLCSP), and ball grid array (BGA). This categorization and affiliated nomenclature is partially based on the solder bump size and the type of equipment used to create the bump. Pushing the limits of each of the three traditional bumping technologies has allowed some overlap between these bumping classifications. But for the most part, volume manufacturing of Flip Chip, WLCSP, and BGA bumps are carried out using different processes steps on different types of equipment. Solder Sphere Placement is a technique that has been shown to completely bridge this technology gap. The basic principle of this technology is to simultaneously pick up preformed solder spheres using a patterned vacuum plate and then accurately place them onto the bond pads of the wafer.

The Solder Sphere Placement technique allows a single technology to be used for an array of different bumping applications. These include:

All wafer sizes from 100 to 300mm and Fan-Out substrates

All solder alloys (lead based, lead-free, polymer core)

FC, WLCSP, and BGA bump sizes (60-760µm spheres)

This up-and-coming technology has been associated with several different names in the literature. These include: Gang Ball Placement, Solder Ball Transfer, Wafer Level Solder Sphere Transfer, Ultra Solder Ball Bumping, and Solder Sphere Placement.

The versatility of this technology can be further enhanced by coupling several other technologies into the solder sphere placement system. These include adding: 2D inspection capabilities, single sphere removal and replacement capabilities (repair and rework), and in-situ solder reflow (inert atmosphere hotplate).

The ultimate Solder Sphere Placement system incorporates all of these discrete technologies into a single tool in order to increase versatility and assure high yields. The final configuration of the tool is often dictated by the product distribution (Flip Chip vs WLCSP vs BGA volumes).

Figure 1. Solder Sphere Placement Tool.

Wafers or substrates for WLCSP and BGA applications have relatively large solder bumps and have relatively few interconnects compared to Flip Chip applications. These larger spheres are placed in extremely high yields by the Solder Sphere Placement tool and the added expense of incorporating inspection and rework capabilities might not be justified. High I/O Flip Chip applications, on the other hand, often require very high bump yields in order to achieve high die yields. In these applications, integration of all the options makes good economical and throughput sense.

The recent availability of highly uniform solder spheres at lower costs has allowed the technique of Solder Sphere Placement to expand within the industry. Typical lead-free spheres (SAC alloys) range in price between $25-50 per million when purchased in volume. As the volume of sphere consumption continues to increase, the cost will continue to come down. Spheres of other alloys, including polymer core and copper core spheres, are also starting to become more prevalent within the industry as alternatives to SAC alloys.

Process Flow

A predetermined number of spheres are automatically dispensed into a sphere reservoir (see Figure 2). The amount of spheres in this reservoir is important in order to achieve high transfer yields. This value is approximately 20-30% more than the number of I/O on the wafer.

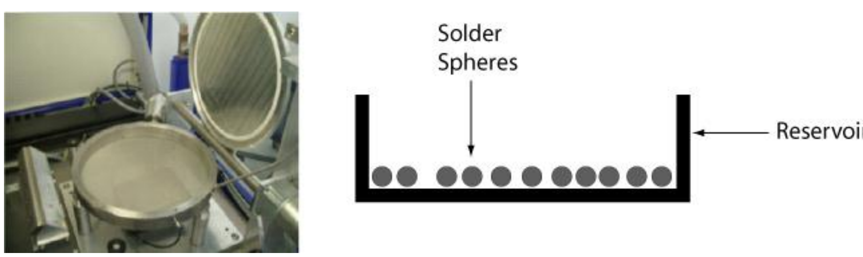

Figure 2. Solder sphere reservoir filled with solder spheres.

The fixture which picks up the spheres consists of two main components: a vacuum head which is mounted to a high precision x-y-z translation stage and a tooling plate which contains small holes that is mechanically mounted to the vacuum head (see Figure 3).

The tooling plate is patterned with openings that correspond directly with the locations of the I/O pads on the wafer. This tooling is created using similar methods to that of making a nickel plated surface-mount stencil. There are a large number of vendors who can now manufacture these stencils using electroforming techniques. The size of openings in the tooling plate is designed to be slightly smaller than the size of spheres that will be placed onto the wafer.

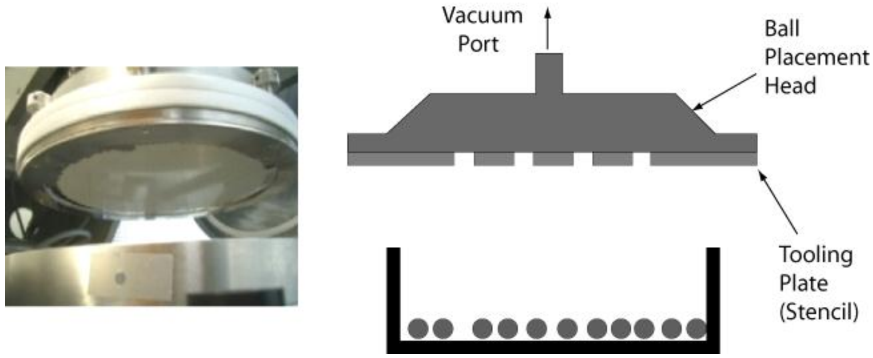

Figure 3. Sphere placement head positioned over the solder sphere reservoir.

The sphere placement head is then lowered onto the sphere reservoir and the vacuum is applied to the vacuum port (see Figure 4). The vacuum alone is not sufficient to efficiently transport and relocate the solder spheres into each opening in the stencil template. The application of ultrasonics is applied to the reservoir to aid in sphere movement.

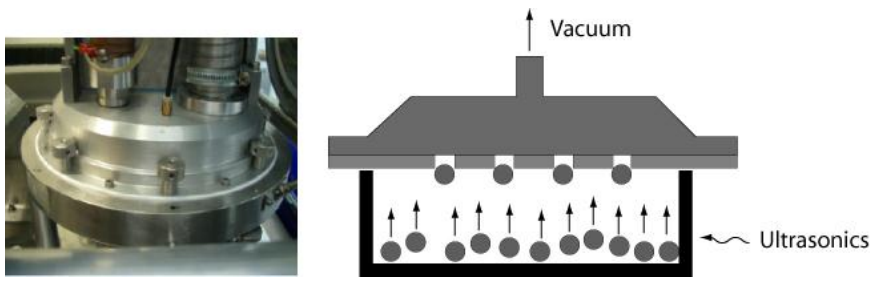

Figure 4. Sphere placement head lowered onto sphere reservoir. Vacuum and ultrasonics applied to reservoir.

Optimization of the ultrasonic amplitude and frequency, in addition to the vacuum, is required for each spheres size and I/O density in order to maximize sphere relocation to the template. Even with this optimization, an unwanted sphere can occasionally adhere to the stencil. This is commonly a result of static electricity. Removal of these extra spheres is accomplished passing the head over a deionizing air knife (see Figure 5).

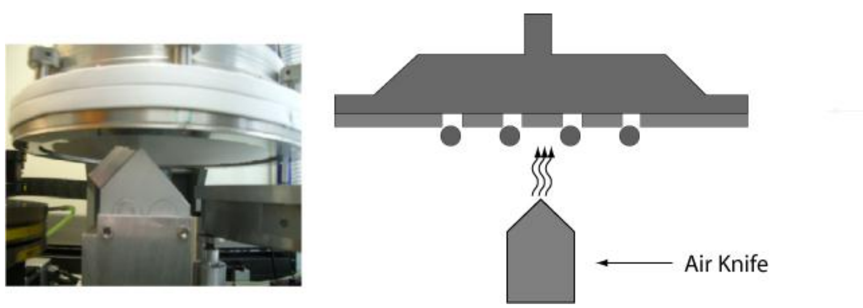

Figure 5. Shear placement head with solder spheres passing over deionizing air knife to remove any excess spheres.

The placement head is then moved over to the transfer station within the tool. A prefluxed wafer has been pre-positioned from a wafer cassette onto the vacuum chuck at this station (see Figure 6). The application of tacky flux is applied in a separate tool prior to being loaded into the sphere placement tool. For WLCSP and BGA applications, screen-printing or stencil printing are used to apply this flux. For Flip Chip applications, spin coating is used to apply the flux. The important criteria for all applications include flux thickness and viscosity.

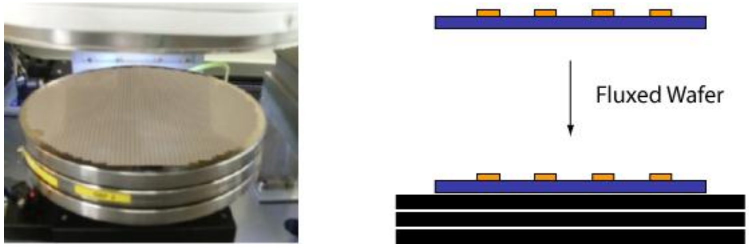

Figure 6. A pre-fluxed wafer is automatically placed onto the vacuum wafer chuck.

The solder transfer head is then moved over the wafer chuck and a bidirectional optical sensor is extended in between the head and the chuck (see Figure 7). This inspection system allows the spheres within the apertures of the stencil template to be aligned to the bond pads on the wafer. In addition to alignment, this sensor performs a 2D scan of the stencil template to confirm that all apertures contain a solder sphere and also inspects for unwanted stray spheres that may still be attached to the template. The tool software can then make a decision based on user criteria to continue to the transfer step, return further cleaning at the air knife station, or go completely back to the sphere pickup station to fill in empty apertures with spheres.

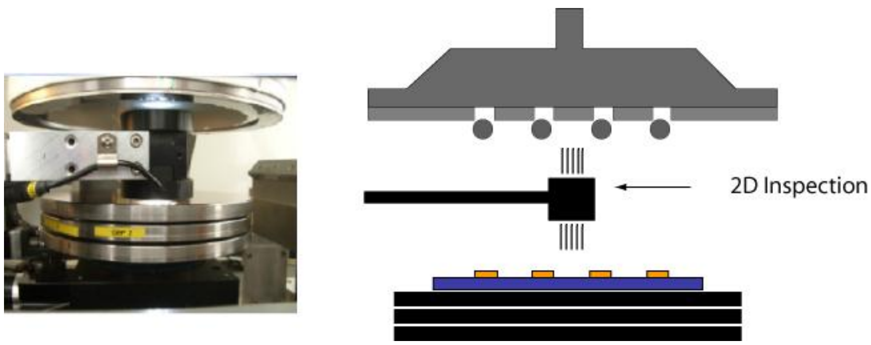

Figure 7. Optical sensor extended between the wafer and placement head. Aligning the template to the wafer and also inspecting for missing or unwanted spheres.

The solder placement head is then lowered toward the wafer until the solder spheres penetrate the flux and touch the wafer bond pads (see Figure 8). The mechanical downward force is adjusted to help drive the spheres onto the pads. The vacuum is then released and a N2 back pressure is applied to the placement head to assist in releasing the spheres.

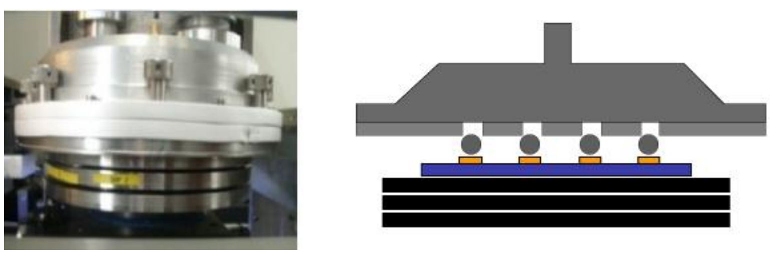

Figure 8. Tooling head lowered on wafer to bring spheres into contact with the fluxed wafer pads.

The head is then raised and the optical inspection sensor is reinserted over the wafer, and the wafer is scanned to quantify transfer yields (see Figure 9). This scan will document the x-y coordinates of any missing or misplaced spheres that may have moved after the transfer process.

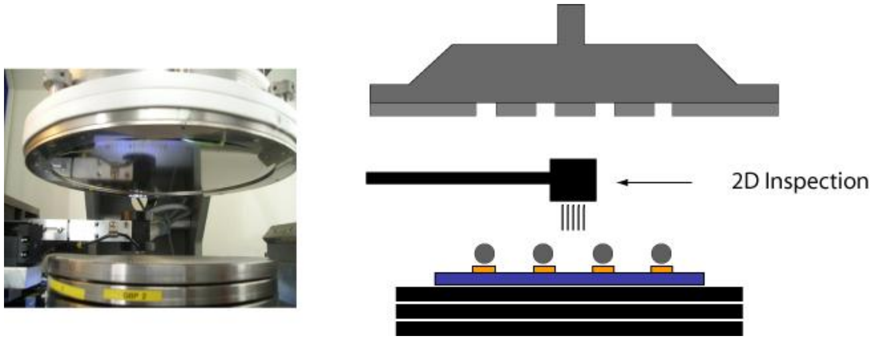

Figure 9. Raise placement head and insert optical sensor over wafer.

For flip chip applications, where high bump yields are an absolute requirement to give high die yields, integration of rework/repair capabilities is critical. It is common for high-end applications, such as microprocessors, to have hundreds of interconnects per die. Even small bump yield losses can translate into high die yield losses.

A repair head, which is based on the SB^2 ™ sphere bumping process [3], is used to repair any defects identified in the 2D inspection (see Figure 10). For missing bumps, a sphere is dropped onto the pad where the bump is missing [10-12]. This process has no mechanical contact with the wafer and solder bumps are deposited at a rate of 6-10 spheres per second. For misplaced or damaged spheres, the capillary head of the SB^2 tool is lowered over the sphere, the capillary heated, and a vacuum is applied to the tube which removes the sphere. In both cases a laser pulse can be added to help liquify the flux or melt the solder sphere.

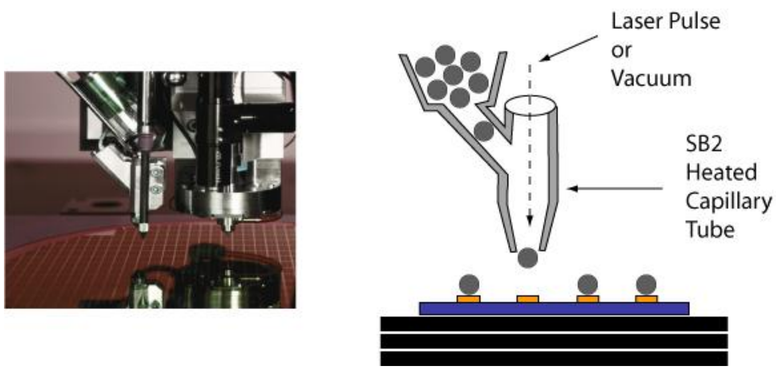

Figure 10. Solder jetting repair head positioned over a pad with a missing solder bump.

The wafer is then ready for final reflow. For most WLCSP and BGA devices the wafers are placed back into the wafer cassette. Once all 25 wafers are bumped, the cassette is moved over to a linear conduction oven for reflow. Alternatively the wafers can be moved over to a reflow chamber located within in the tool (see Figure 11). This is more common for fine pitch Flip Chip devices.

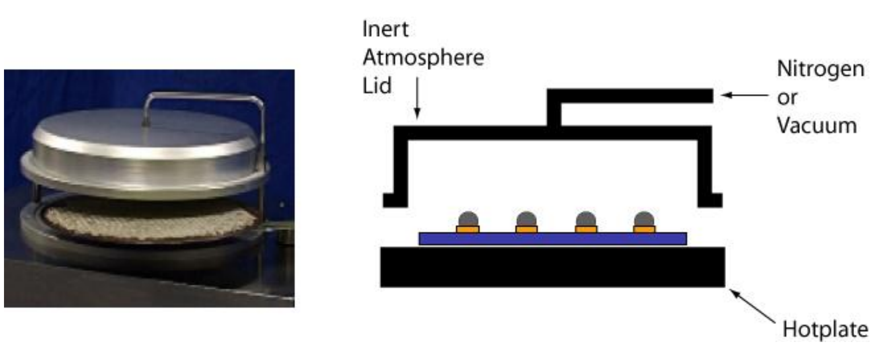

Figure 11. Solder bumps reflowed on heated vacuum chuck.

After reflow, the wafers are placed back into the process cassette and cleaned in a batch process using a combination of ultrasonics, solvents, and water rinsing (see Figure 12).

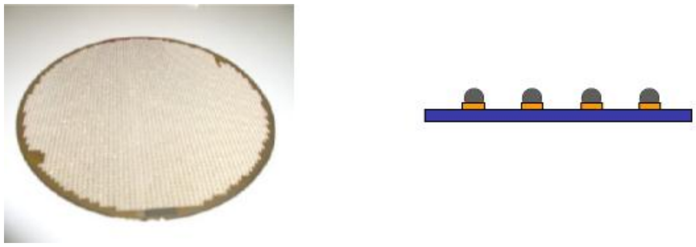

Figure 12. Bumped, reflowed and cleaned wafer.

Conclusions

The Wafer Level Solder Sphere Placement tool can perform flip chip, WLCSP, and BGA bumping operations (see Figure 13). The configuration of the tool is dictated by the product distribution (see Tables 1 and 2). Defects in the ppm range result in die yields greater than 99%. Wafer throughputs are between 20-45 wafers per hour.

Table 1. Process Steps for WLCSP and BGA Applications.

Process Step	Equipment
1. Flux Deposition	Stencil or Screen Printer
2. Sphere Transfer	Basic Solder Sphere Placement
3. Reflow	Linear Oven
4. Wafer Clean	Solvent and/or DI Water Tools
5. Inspection	2D Scanner

Table 2. Process Steps for Flip Chip Applications.

Process Step	Equipment
1. Fluxing	Spin Coating
2a. Sphere Transfer b. 2D Inspection c. Rework d. Hot Plate Reflow	Integrated Solder Sphere Placement Tool
3. Wafer Clean	Solvent and/or DI Water

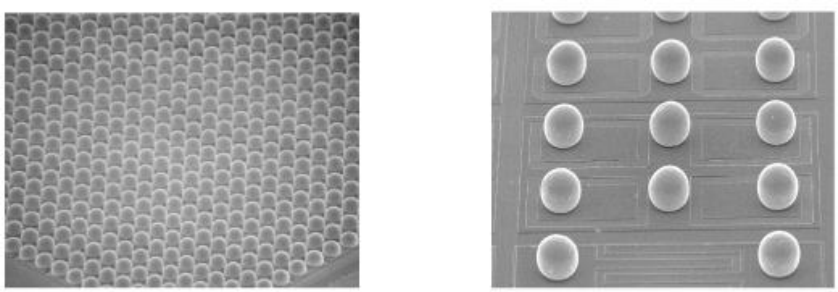

Figure 13. SEM Image of 60μm Flip Chip Bumps and 300μm WLCSP Solder Bumps.

ACKNOWLEDGEMENTS

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WLCSP AND FLIPCHIP PRODUCTION BUMPING USING ELECTROLESS Ni/Au PLATING AND WAFER LEVEL SOLDER SPHERE TRANSFER TECHNOLOGIES

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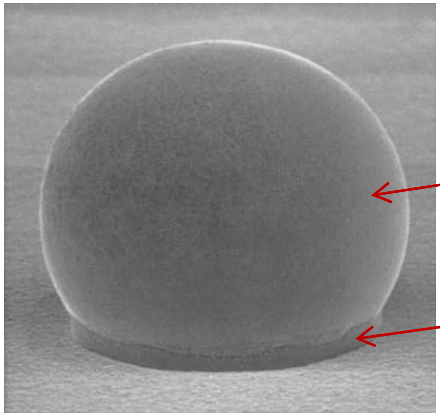
Presentation Outline

1. e-Nickel/Gold UBM
2. Solder Sphere Transfer
3. Process Evaluation
4. Cost Model



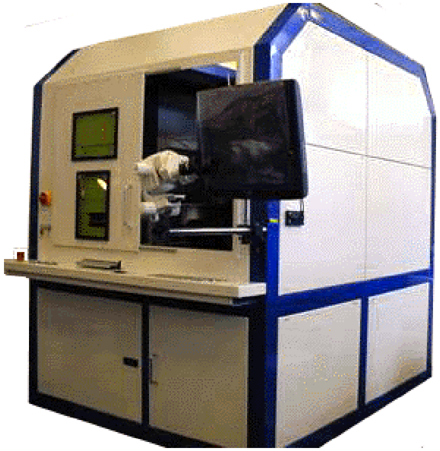
WLCSP Bump

ELECTROLESS Ni/Au PLATING

PacLine 3000

1) Yield
2) Throughput
3) Cost

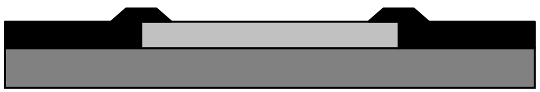
WAFER LEVEL SOLDER SPHERE TRANSFER



ultra-SB²

Under Bump Metallization (UBM)

UBM - Under Bump Metallurgy (Most of World)
BLM - Bump Limiting Metallurgy (IBM)
UBL - Under Bump Layer (Japan)



Integrated Circuit (I/O pad)

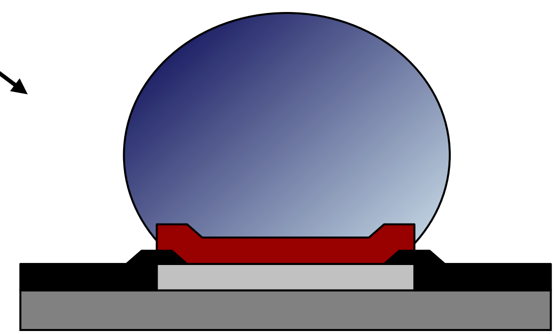
UBM Functions:

1) Solderable surface
2) Electro-migration barrier
3) Thermal-migration barrier
4) Increase standoff
5) Current distribution
6) Protect final metal

UBM

UBM Requirements:

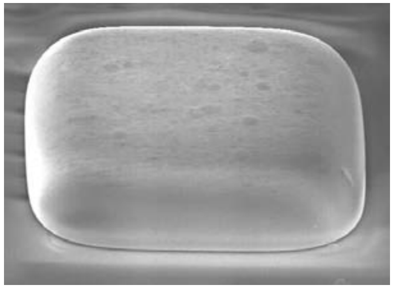
1) Adhesion to pad metal
2) Low stress
3) Low electrical contact resistance
4) Compatibility with probed I/O pads
5) Compatible with bump (SnPb, SnAgCu, SnAu, Epoxy,…)



Bump

Common Under Bump Metallizations

1) Sputtered:	Al/NiV/Cu Ti/NiV/Au, etc…	Delco Electronics “Flex-on-Cap” Smaller volumes - research
2) Evaporated:	Cr/CrCu/Cu	IBM technology from “C4” era
3) Electroplated:	Cu Pillar Au Bump	High standoff Significant volumes in Japan
4) Printed:	Silver Alloys Nanotechnology	Next generation R&D
5) Electroless:	Nickel/Gold Nickel/Palladium	Lowest cost



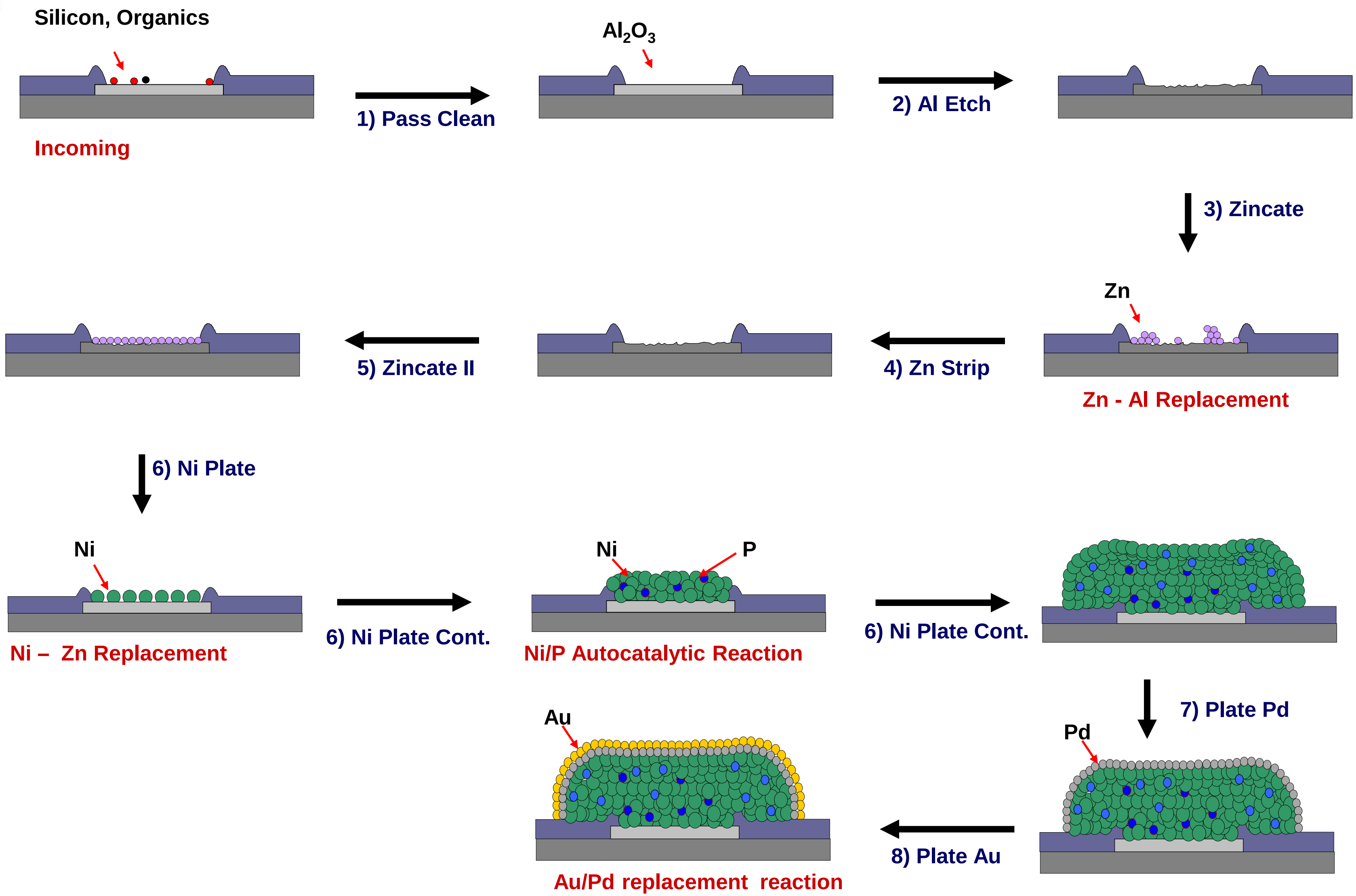
Wet Chemical Process
Batch Process (>50 wafers/hr)
No Photolithography or High Vacuum Processing
Used for WLCSP, Flip Chip, ACA, Stub Bumping

Electroless Ni/Au Bump

UBM: Process Flow Comparisons

1 Sputtered (Ti/NiV/Cu)	2 Evaporative (Cr/CrCu/Cu)	3 Electroplated (Cu or Au)	4 Printed (Ag)	5 Electroless (Ni/Au)
1) Clean Pad Metal	1) Clean Pad Metal	1) Clean Pad Metal	1) Print Metal	1) Plate e-Ni/Au
2) Sputter Ti/NiV/Cu	2) Apply Photoresist	2) Sputter Ti/Cu Seed		
3) Apply Photoresist	3) Soft-bake Photoresist	3) Apply Photoresist		
4) Soft-bake Photoresist	4) Photo-expose Resist	4) Soft-bake Photoresist		
5) Photo-expose Resist	5) Image Reversal Bake	5) Photo-expose Resist		
6) Develop Resist	6) Flood Expose	6) Develop Resist		
7) Post Bake	7) Develop Resist	7) Post Bake		
8) Plasma Descum	8) Plasma Descum	8) Plasma Descum		
9) Wet Etch Cu	9) Evaporate Cr/CrCu/Cu	9) Plate Cu or Au		
10) Dump Rinse	10) Solvent Lift Off	10) Dump Rinse		
11) Wet Etch NiV	11) Solvent Clean	11) Strip Photoresist		
12) Dump Rinse	12) Dump Rinse/SRD	12) Dump Rinse		
13) Wet Etch Ti		13) Wet Etch Ti /Cu Seed		
14) Strip Photoresist		14) Dump Rinse/SRD		
15) Dump Rinse/SRD				

Electroless Ni/Au Process Flow (*Aluminum Based ICs*)



Electroless Ni/Au Plating Video

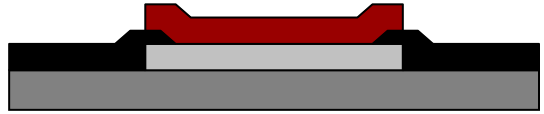
Wafer Bumping

Bump Functions:

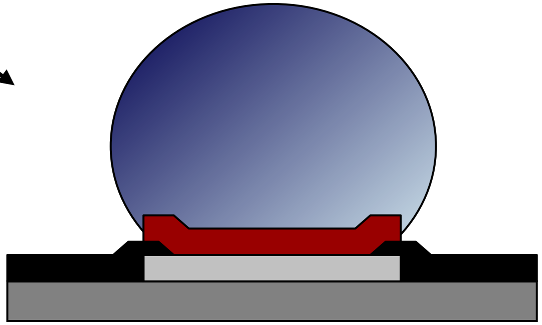
1) Electrical Interconnect
2) Thermal Interconnect
3) Passive Alignment (e/g Optics, MEMs)

Integrated Circuit

(Pad I/O)



UBM



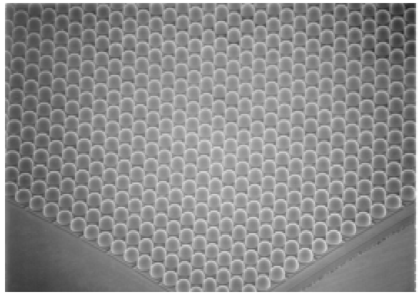
Bump

Bump Requirements:

1) Adhesion to UBM
2) Low electrical resistance
3) High thermal conductivity
4) Stable intermetallic with UBM

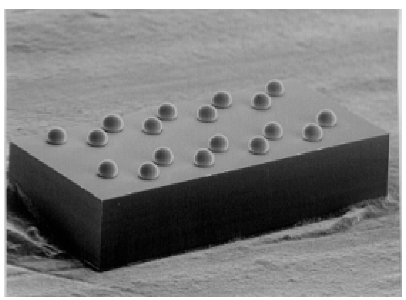
Wafer Bumping - Flip Chip & WLCSP

Flip Chip



Solder is <200μm tall
Underfilled during assembly

WLCSP

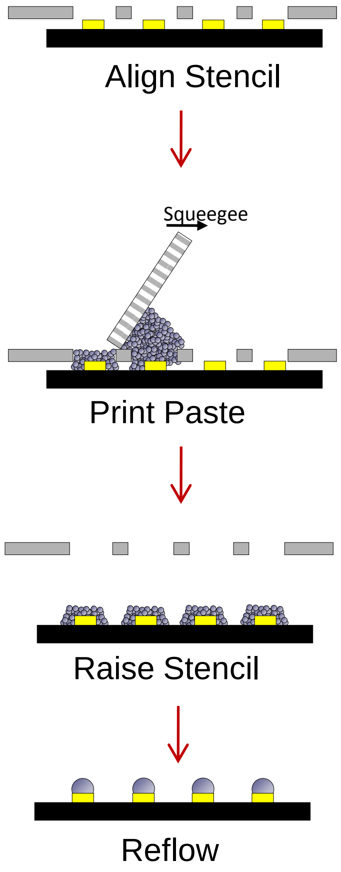


Solder is >200μm tall
No underfill

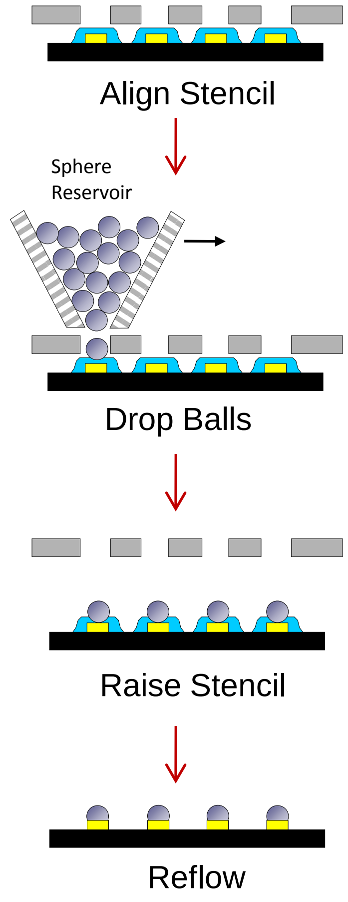
Terms used to describe wafer bumping:

Flip Chip
C4 (IBM)
Flex-on-Cap (Delco)
Solder Interconnect
FCOB (Flip Chip On Board)
C4NP (IBM)
Bumping
Wafer Bumping
Solder Bumping
DCA (Direct Chip Attach)
Micro BGA
Ultra CSP
CSP
WLCSP

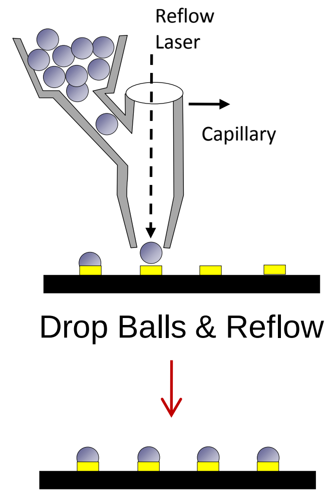
Stencil Print



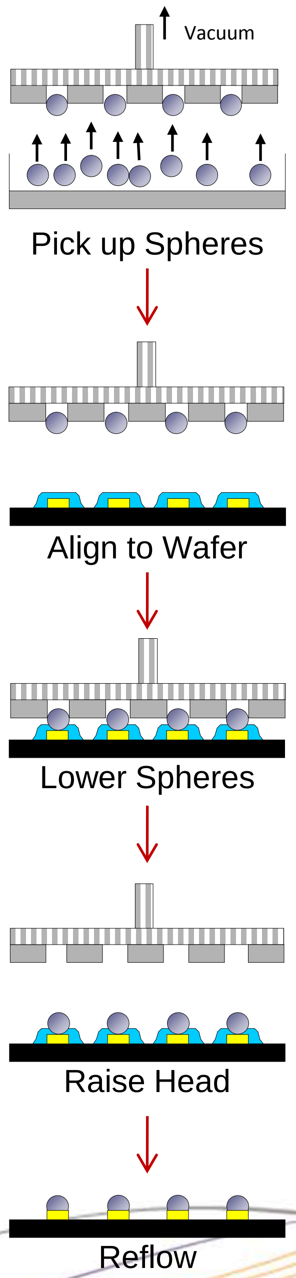
Ball Drop



Laser Jet



Sphere Transfer



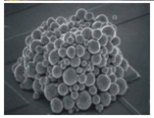
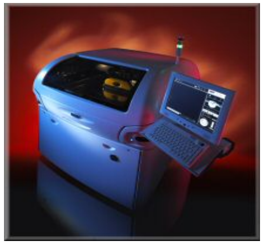
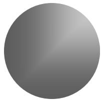
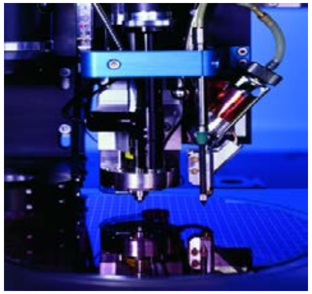
Solder Deposition: Process Flow Comparisons

WLCSP

Stencil Print Solder Paste	Ball Drop	Solder Jet	Wafer Level Solder Sphere Transfer (CSP)
1) Paste Print	**1) Flux**	**1) Solder Jet & Reflow**	**1) Flux**
2) Reflow	**2) Drop**	**2) Inspect**	**2) Transfer**
3) Clean / SRD	**3) Reflow**		**3) Reflow**
4) Inspect	**4) Clean / SRD**		**4) Clean / SRD**
	5) Inspect		**5) Inspect**

Flip Chip

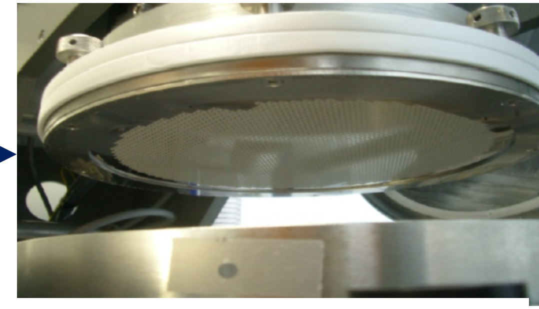
Wafer Level Solder Sphere Transfer (Flip Chip)
1) Flux/Drop/Reflow/Inspect/Rework
2) Clean / SRD

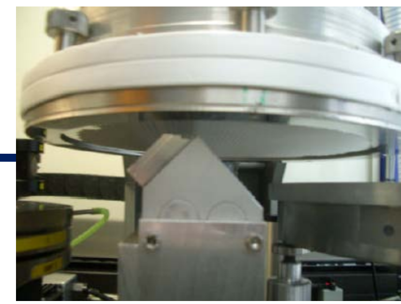






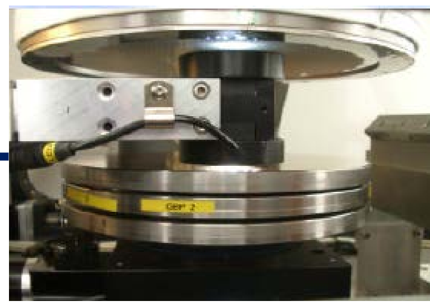
Wafer Level Solder Sphere Transfer (Gang Ball Placement)

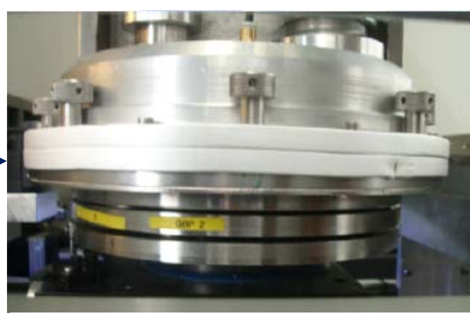

Solder Spheres in Reservoir

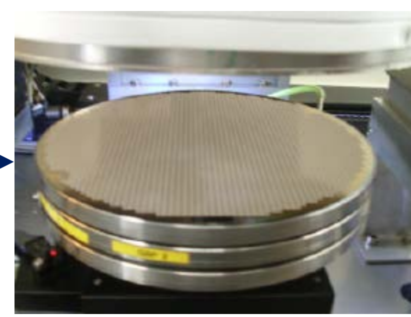

Vacuum Head Lowered into Solder Spheres Reservoir

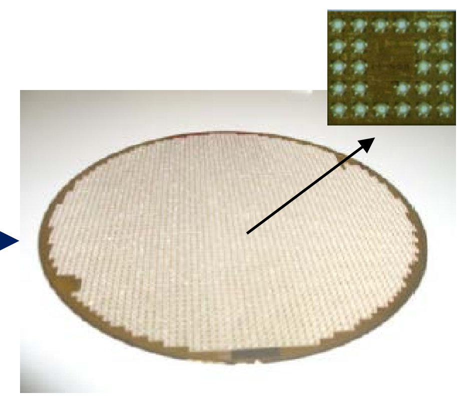

Solder Spheres Attached on Vacuum Tooling Plate


Removing Excess Solder Spheres via Air Knife

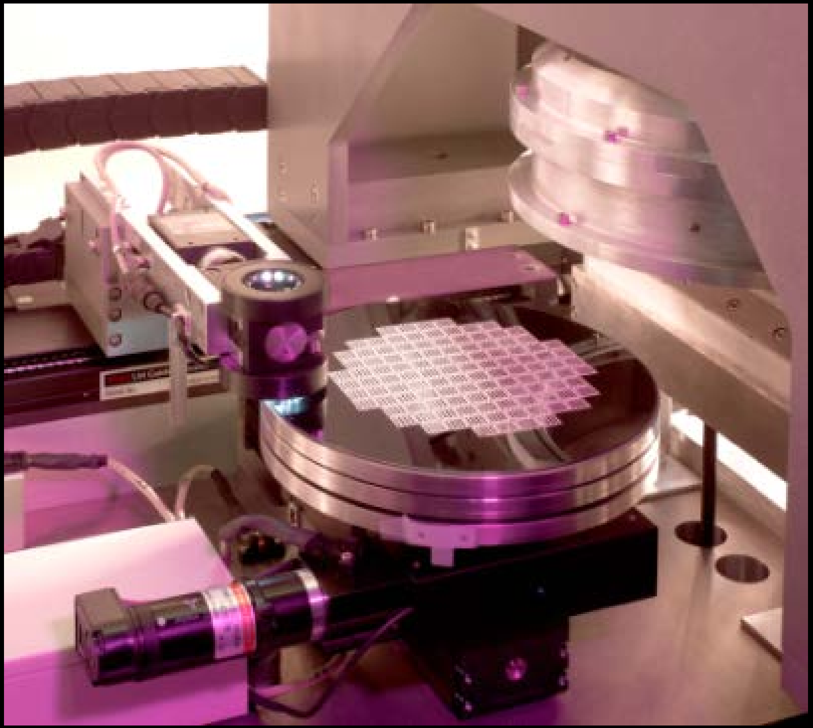

Align tooling with Wafer (via double vision camera)


Lower Head onto Wafer and Bring Spheres into Contact with I/O Pads


Raise Transfer Head


Remove Wafer for Reflow and Clean

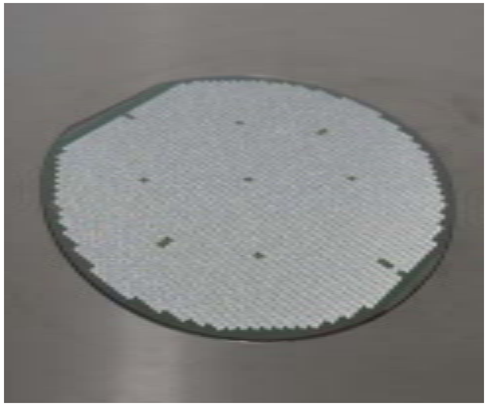
Wafer Level Solder Sphere Transfer Video



Process Evaluation – Wafer Level Solder Sphere Transfer

Process Step	Equipment	Yield	Wafers/Hr
1. UBM Deposition	e-Ni/Au (PacLine 3000)		
2. Flux Deposition	Spin Coater (Spin Pac SC200)		
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB^2)		
4. Reflow	Linear Oven (Sikama)		
5. Wafer Clean	Solvent Clean (MegaPac MP300)		
6. Inspection	Microscope (Olympus MX50)		

1) Yield
2) Throughput



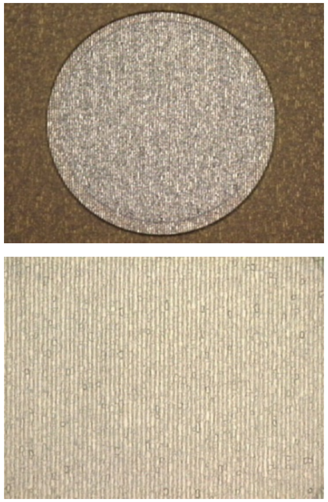
Test Vehicle Properties

Wafer Size	200 mm
Wafer Thickness	360 µm
Die per wafer	3175
I/O per die	25
I/O on the wafer (bumped)	79,375
Pad Size	240 µm
Pad Pitch	500 µm
Pad Metallurgy	Al w/0.5%Cu

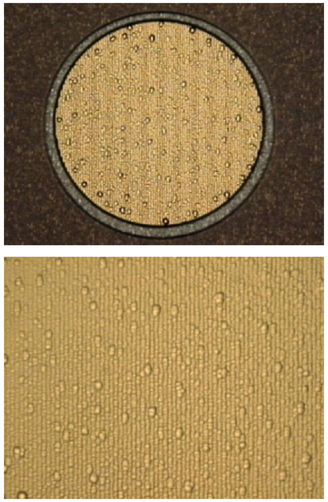
Process Evaluation – Wafer Level Solder Sphere Transfer

Process Step	Equipment	Yield	Wafers/Hr
1. UBM Deposition	e-Ni/Au (PacLine 3000)	100	50
2. Flux Deposition	Spin Coater (Spin Pac SC200)		
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB^2)		
4. Reflow	Linear Oven (Sikama)		
5. Wafer Clean	Solvent Clean (MegaPac MP300)		
6. Inspection	Microscope (Olympus MX50)		

Al Bond Pad



Ni/Au Plated Pad



Ni/Au Plating Parameters/Results

Nickel Thickness	5 µm
Gold Thickness	600 Å
Ni/Au Plating Time (50 per batch)	55 min
Throughput	50 wafers/hr
Plating Yield	100 %

APEX EXPO IPC

Process Evaluation – Wafer Level Solder Sphere Transfer

Process Step	Equipment	Yield	Wafers/Hr
1. UBM Deposition	e-Ni/Au (PacLine 2000)	100	50
2. Flux Deposition	Spin Coater (Spin Pac SC200)	100	60
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB^2)		
4. Reflow	Linear Oven (Sikama)		
5. Wafer Clean	Solvent Clean (MegaPac MP300)		
6. Inspection	Microscope (Olympus MX50)		

Flux Options:
1) Spin Coat
2) Stencil Print
3) Screen Print
4) Spray Coat
5) Sphere Dip

Flux Purpose:
1) Remove oxides from solder surface
2) Adhere sphere to the pad prior to reflow (tackiness)

Flux Thickness:
1) Too thick the sphere will float during reflow
2) Too thin the sphere will not adhere during placement

Flux Parameters/Results

Flux Type	Water Soluble
Fluxing Method	Spin Coat
Flux Thickness	1-3 mils
Process Time (25 wafers)	25 min
Throughput	60 wafers/hr

Process Evaluation – Wafer Level Solder Sphere Transfer

Process Step	Equipment	Yield	Wafers/Hr
1. UBM Deposition	e-Ni/Au (PacLine 2000)	100	50
2. Flux Deposition	Spin Coater (Spin Pac SC200)	100	60
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB^2)		30
4. Reflow	Linear Oven (Sikama)		
5. Wafer Clean	Solvent Clean (MegaPac MP300)		
6. Inspection	Microscope (Olympus MX50)		

Sphere Parameters

Sphere Size	300 µm
Sphere Uniformity	± 5 µm
Solder Alloy	SAC305

Tooling Parameters (Vacuum Plate)

Aperture Size	150 µm
Stencil Thickness	120 µm
Stencil Material	Electroformed (Ni Plated)

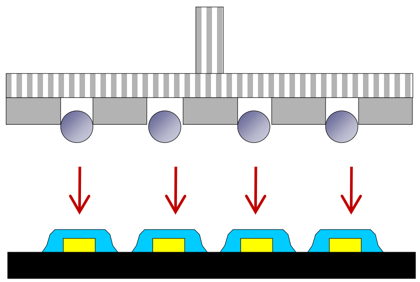
1) Pre-fluxed wafers in a cassette (25)
2) Load Cassette into GBP Tool
3) Process 25 wafers
4) Remove Cassette

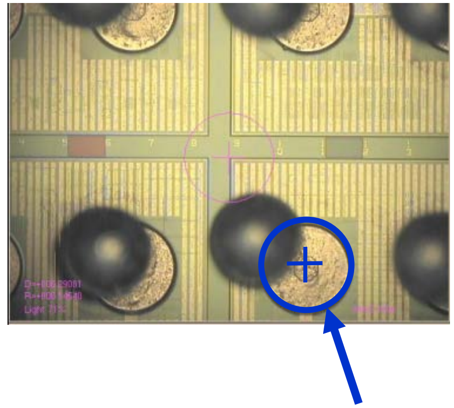
Process Parameters/Results

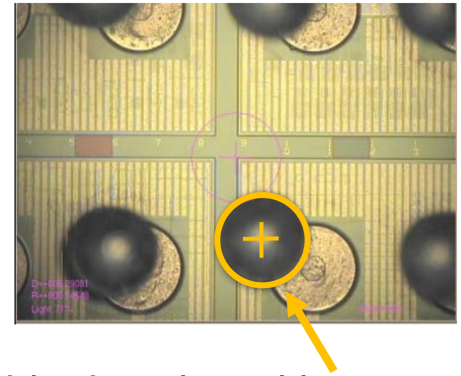
Transfer Time (25 Wafers)	50 min
Throughput	30 wafers/hr

WLSST Process Characterization: Solder Sphere Placement Accuracy

1) Flux Wafer
2) Transfer Spheres
3) Measure Offset
4) Clean Wafer
5) Repeat 25x





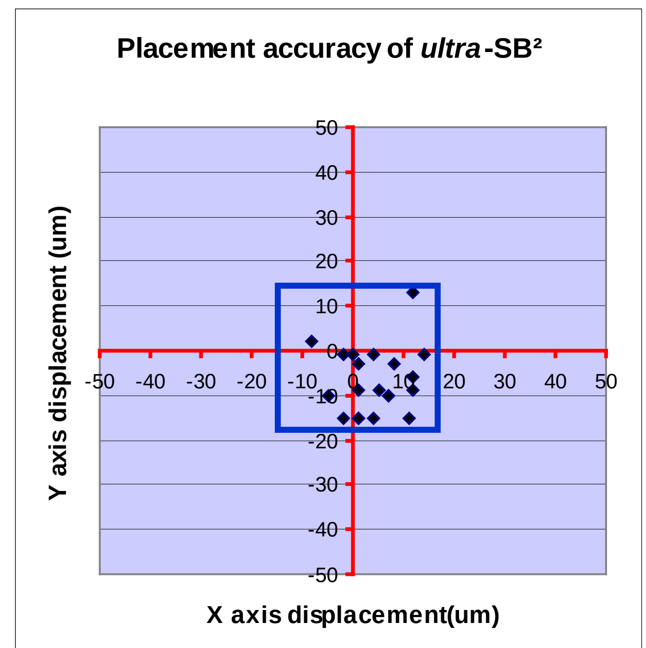


Pad location is **(0,0)**

Solder location with respect to pad location is **(x' , y')**

Process Statistics (microns)

	x	y
Minimum	**-8.00**	**-15.00**
Maximum	**14.00**	**13.00**
Average	**4.15**	**-6.65**
Std Deviation	**6.18**	**7.31**



Placement Accuracy Window of ±15µm

Process Evaluation – Wafer Level Solder Sphere Transfer

Process Step	Equipment	Yield	Wafers/Hr
1. UBM Deposition	e-Ni/Au (PacLine 2000)	100	50
2. Flux Deposition	Spin Coater (Spin Pac SC200)	100	60
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB^2)	99.999	30
4. Reflow	Linear Oven (Sikama)		
5. Wafer Clean	Solvent Clean (MegaPac MP300)		
6. Inspection	Microscope (Olympus MX50)		

Sphere Yield

I/O placed with spheres (25 wafers)	Good Bumps	Yield Loss	%Yield	ppm
1984375	1984353	22 bumps	99.999%	9

Die Yield

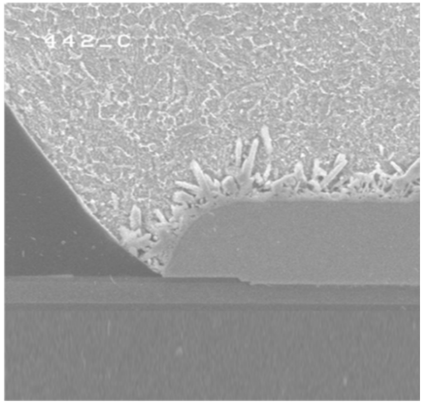
Dies placed with spheres (25 wafers)	Good Dies	Yield Loss	%Yield	ppm
79375	79362	13 die	99.986%	139

Process Evaluation – Wafer Level Solder Sphere Transfer

Process Step	Equipment	Yield	Wafers/Hr
1. UBM Deposition	e-Ni/Au (PacLine 2000)	100	50
2. Flux Deposition	Spin Coater (Spin Pac SC200)	100	60
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB^2)	99.999	30
4. Reflow	Linear Oven (Sikama)	100	60
5. Wafer Clean	Solvent Clean (MegaPac MP300)		
6. Inspection	Microscope (Olympus MX50)		

Reflow Options:

1) Conduction Oven
2) Convection Oven
3) Hot Plate



Reflow Specifications:

Melt solder to UBM
1) Consume Au Layer
2) Create intermetallics SnNi

Process Parameters/Results

Reflow Process	Conduction Oven
Peak Temperature	240 degC
Time at Temp	20 sec
Transfer Time (25 Wafers)	15 min
Throughput	60 wafers/hr

Process Evaluation – Wafer Level Solder Sphere Transfer

Process Step	Equipment	Yield	Wafers/Hr
1. UBM Deposition	e-Ni/Au (PacLine 2000)	100	50
2. Flux Deposition	Spin Coater (Spin Pac SC200)	100	60
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB^2)	99.999	30
4. Reflow	Linear Oven (Sikama)	100	60
5. Wafer Clean	Solvent Clean (MegaPac MP300)	100	60
6. Inspection	Microscope (Olympus MX50)		

Clean Options:

1) Water Clean (QDR)
2) Water High Pressure Spray
3) Solvent Clean
4) Solvent & Ultrasonics

Clean Specifications:

1) Remove all flux residues
2) Must Not damage solder

Process Parameters/Results

Clean Process	Megasonic
Chemistries	Mixed Solvent
Temperature	70 degC
Process Time (25 Wafers)	15 min
Throughput	60 wafers/hr

Process Evaluation – Wafer Level Solder Sphere Transfer

Process Step	Equipment	Yield	Wafers/Hr
1. UBM Deposition	e-Ni/Au (PacLine 2000)	100	50
2. Flux Deposition	Spin Coater (Spin Pac SC200)	100	60
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB^2)	99.999	30
4. Reflow	Linear Oven (Sikama)	100	60
5. Wafer Clean	Solvent Clean (MegaPac MP300)	100	60
6. Inspection	Microscope (Olympus MX50)	100	5

Inspection Options:

1) Microscope (100%)
2) Microscope (sampling)
3) 3D Scanning
4) 2D Scanning
5) Electrical Probe

Inspection Specifications:

1) Detect all defects
2) Characterize all defects e.g. missing bumps,…
3) Document location of defects

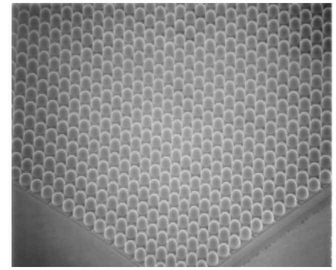
Process Parameters/Results

Inspect Process	Microscope (100%)
Process Time (25 Wafers)	5 hours
Throughput	5 wafers/hr

Wafer Level Solder Sphere Transfer for Flip Chip Applications

Increase accuracy of sphere placement:

1) High precision translation systems (±5 μm)
2) Increased mechanical structure
3) Fine pitch vacuum Plate (stencil)
4) Options
   a. Flux
   b. Reflow (hotplate)
   c. 2D Inspection
   d. SB² Rework



Flip Chip Challenges:

60 - 200 μm spheres
80 - 150 μm pad pitch
> 2000 bumps per die
>500,000 bumps per wafer

150µm sphere size
400µm pad pitch

WLCSP

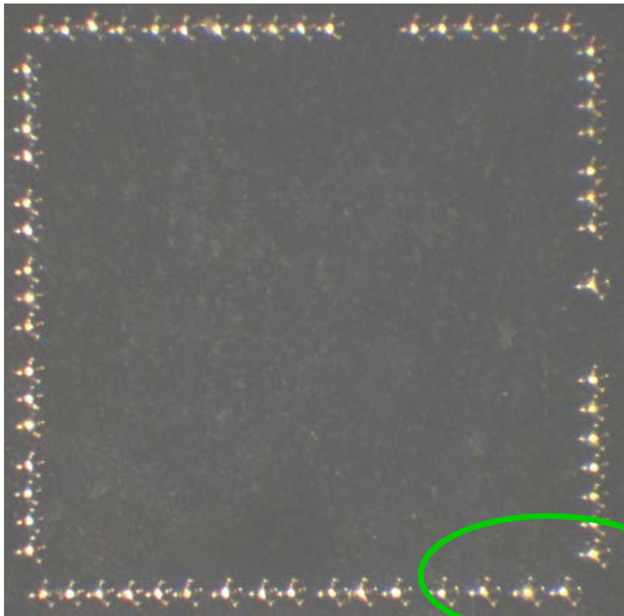
Process Step	Equipment
1. UBM Deposition	e-Ni/Au (PacLine 2000)
2. Flux Deposition	Spin Coater (Spin Pac SC200)
3. Sphere Transfer	Basic WLSST Tool (Ultra-SB² or GBP)
4. Reflow	Linear Oven (Sikama)
5. Wafer Clean	Solvent Clean (MegaPac MP300)
6. Inspection	Olympus MX50

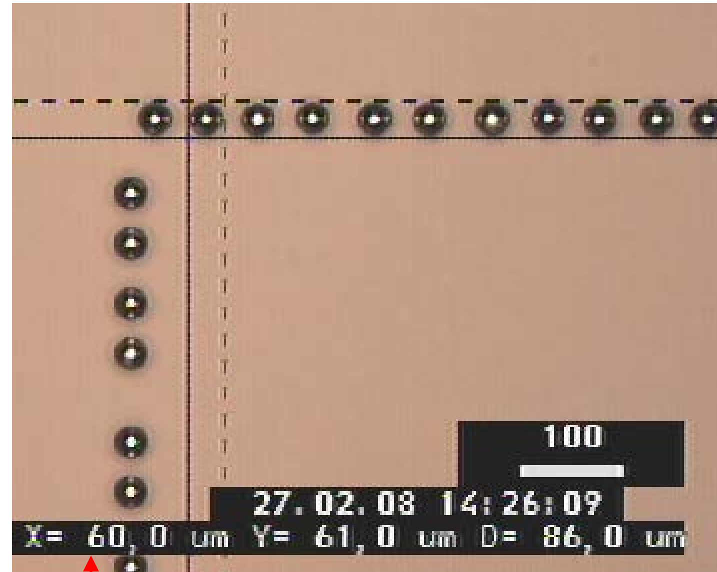
Flip Chip

Process Step	Equipment
1. Flux Dip Sphere Transfer 2D Inspection Rework Hot Plate Reflow	Integrated WLSST Tool (Ultra-SB²)
2. Wafer Clean	Solvent Clean (Megasonic PacTech)

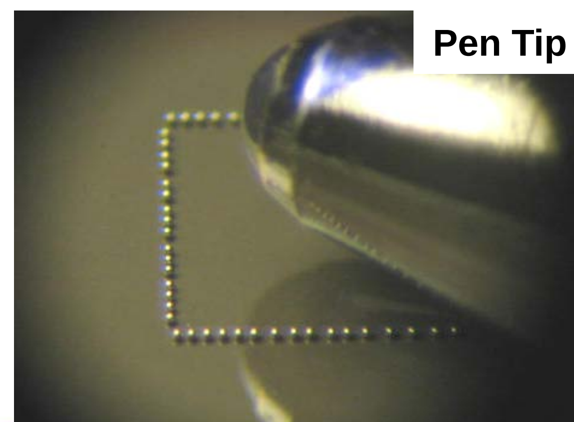
Wafer Level Solder Sphere Transfer for Flip Chip Applications

60µm sphere size / 80µm pad pitch

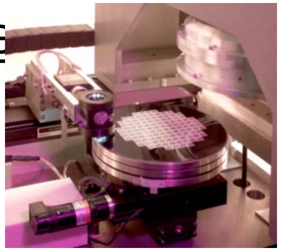




Sphere Size Diameter 60 mm

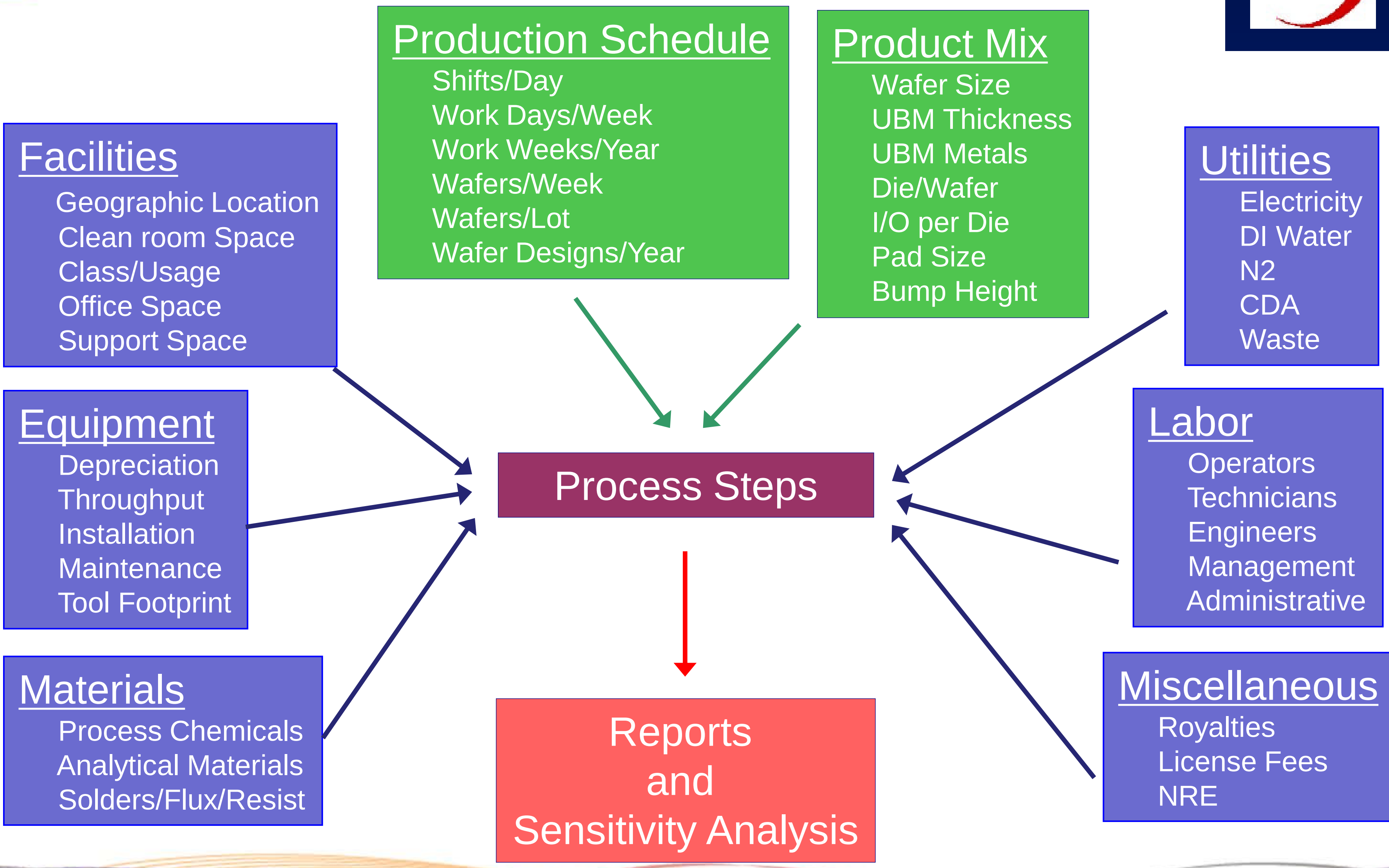


Process Summary - Wafer Level Solder Sphe



Category		WLCSP	Flip Chip
Wafer:	Size	100-300 mm	100-300 mm
Solder :	Format Cost Type	Spheres $25-50 per million spheres lead and lead free	Spheres $35-50 per million spheres lead and lead free
Bump Size :	Range	200 – 750 μm	60 – 200 μm
Placement:	Accuracy	±15 μm	±5 μm
Yield :	Bump	< 25 ppm (wo/repair)	< 10 ppm (w/repair)
Uniformity :	Height	< 10 μm (sphere sizing)	< 5 μm variation (sphere sizing)
Tooling :	Type Cost (ea)	Nickel plated tooling plate $500– 1000 (vendor dependent)	Nickel plated tooling plate $500 – 2000 (vendor dependent)
Throughput :	Wafers	25-45 wafers/hr	12-30 wafers/hr (w/repair)

Cost Resource Model



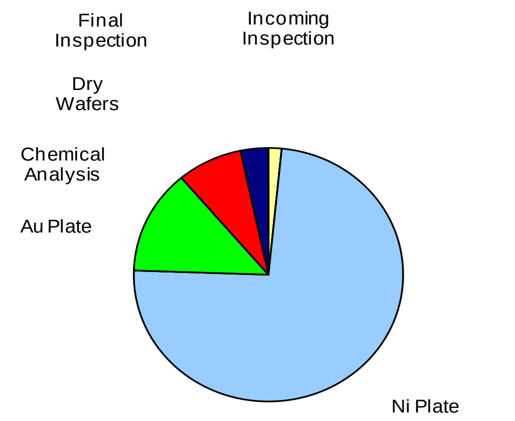
E-Nickel Plating Costs

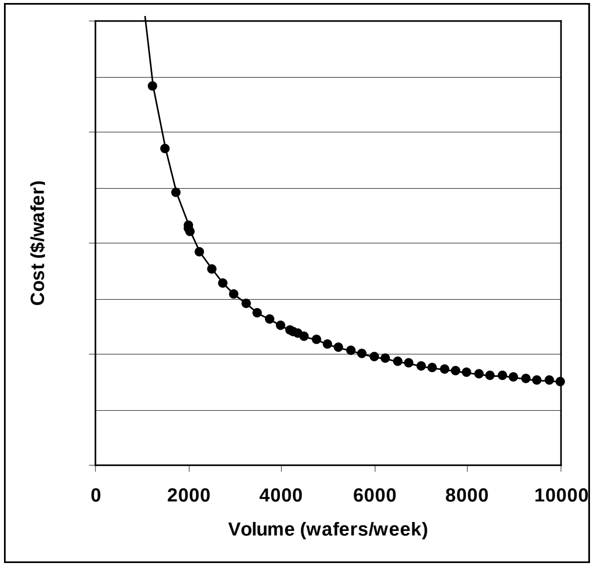
Common Variables	
Shifts/day	3
Hrs/shift	8
Days/week	7
Wks/yr	50
Wafer Size (mm)	200
Pad metallurgy	Al
e-Ni Thickness (um)	5
i-Au Thickness (um)	0.06
Plating Area (%)	10
I/O Diameter (um)	240

e-Ni Process Flow:

1) Incoming Inspection
2) Plate Ni
3) Plate Au
4) Chemical Analysis
5) Dry Wafers
6) Final Inspection

e-Ni Process Steps (3,000 wafers/week)

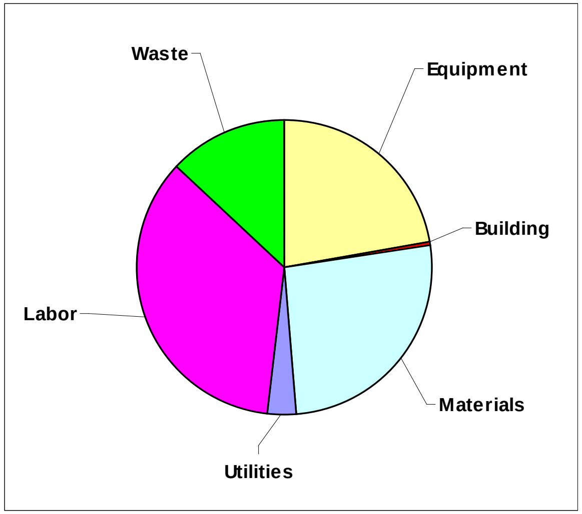




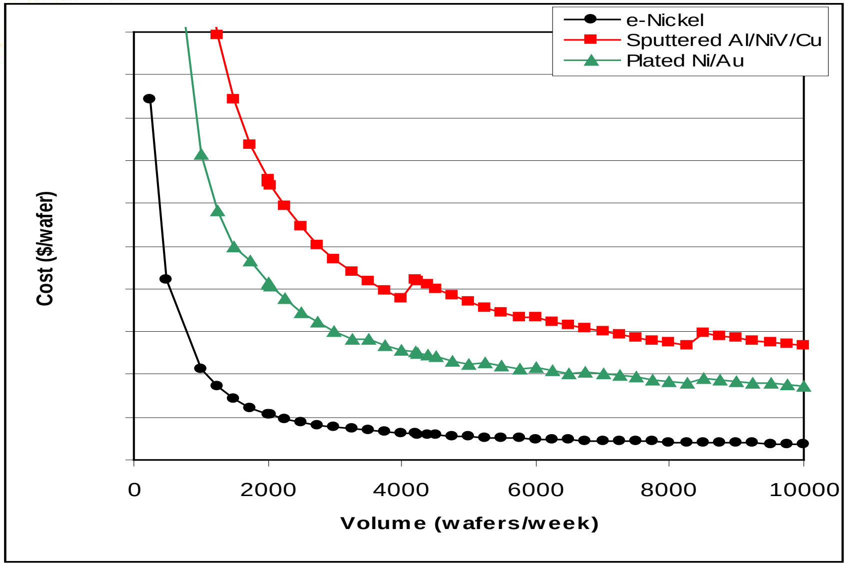
Cost decreases with volume

Not capacity limited

e-Ni Resources (3,000 wafers/week)



e-NiAu vs Sputtered Al/NiV/Cu vs Electroplated Ni/Au



Sputtering and Electroplating:

3-6x the cost of e-Ni/Au

Lower throughput requires more equipment

e-Ni/Pd/Au Process :

1) Incoming Inspection
2) Plate Ni
3) Plate Au
4) Chemical Analysis
5) Dry Wafers
6) Final Inspection

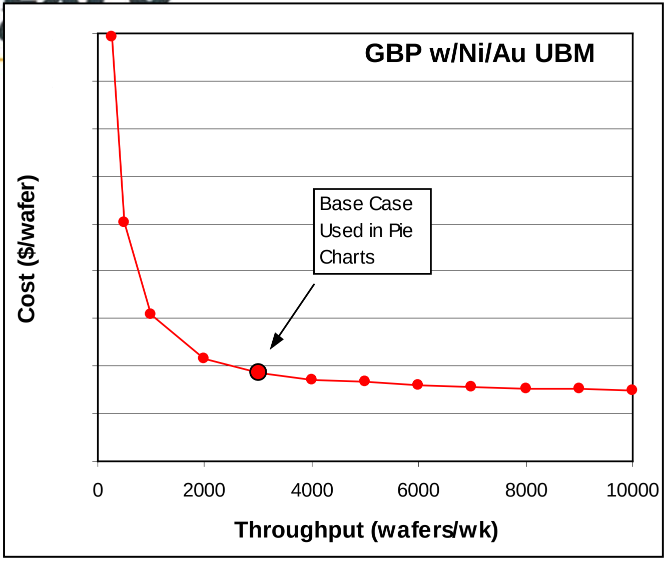
Sputtered Al/NiV/Cu Process :

1) Incoming Inspection
2) Pad Clean
3) PVD Al-NiV-Cu
4) Resist Coat
5) Pattern Resist
6) Descum
7) Etch Metal
8) Strip Resist
9) Clean
10) Final Inspection

Electroplated Ni/Au Process :

1) Incoming Inspection
2) Sputter Seed
3) Coat & Pattern Resist
4) Descum
5) Electroplate Ni
6) Electroplate Au
7) Strip Resist
8) Etch Seed Metal
9) Clean
10) Final Inspection

Solder Sphere Transfer Bumping Costs



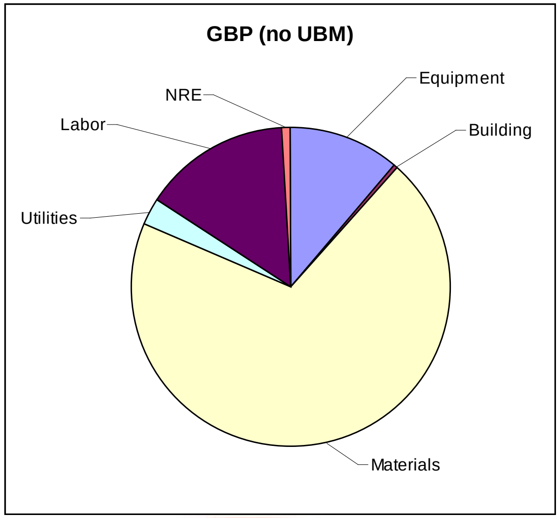
Common Variables	
Shifts/day	3
Hrs/shift	8
Days/week	7
Wks/yr	50
Wafer Size	200
Parts #/year	10
Pad metallurgy	Al
UBM	Ni/Au
I/O per Wafer	250,000
I/O Diameter (um)	240
Sphere Cost ($/M)	50

Spheres costs are significant component of material costs

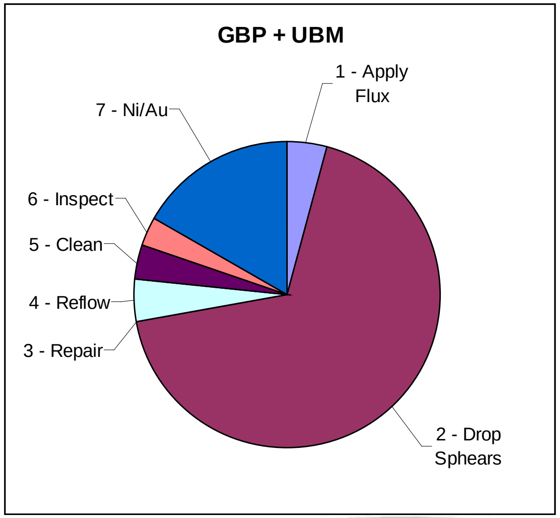
GBP Process Flow:

1) UBM Deposition
2) Flux
3) Sphere Transfer
4) Repair(4%)
5) Linear Oven Reflow
6) Megasonic Clean
7) 2D Inspection (100%)

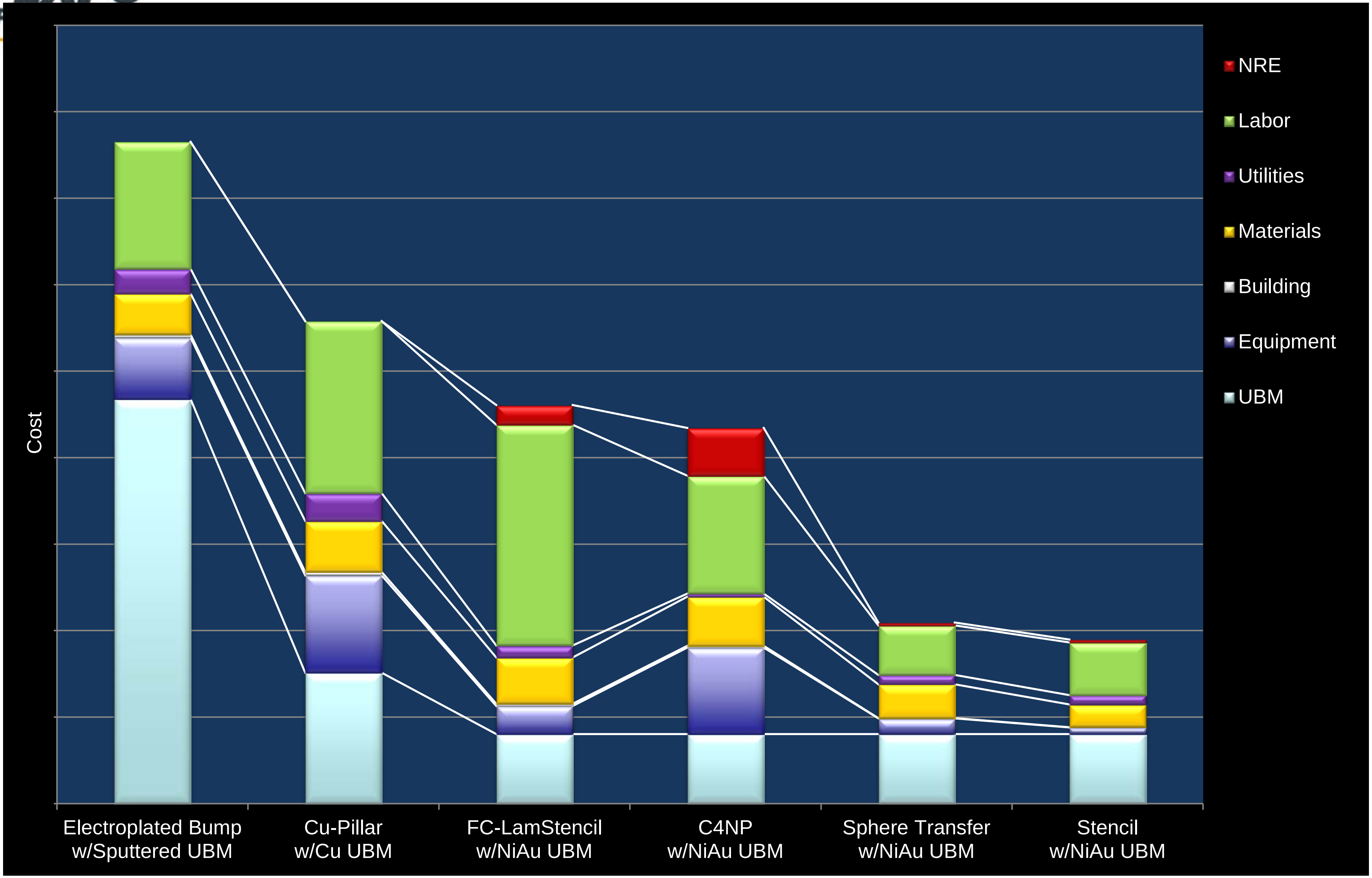
Resources (@3000 wafers/wk)



Process Steps (@3000 wafers/wk)



Wafer Bumping Costs (UBM and Solder)



- One can continuously bump over 25 wafers per hour using e-Ni/Au and Wafer Level Solder Sphere Transfer Technologies
- Bump and die yields were greater than 99.9% (139ppm die yield loss) for wafers with 80,000 I/O (240µm I/O pad on a 500µm pitch using 300µm spheres).
- Placement accuracy is better than ±15µm
- Process capable of placing 60µm sphere size on a 80µm pitch.