Fine Powder Solder Paste Applications for Semiconductor Packaging

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Abstract
Fine solder powder paste applications continue to grow as a cost effective solution to many semiconductor packaging needs. Applications for solder paste continue to evolve from the standard SMT market to the semiconductor backend. This paper describes capability and process details for wafer bumping, substrate bumping, Solder on Pad, BGA ball attach and System in Package applications. For wafer bumping, quantitative bump height data, demonstrated print process, stencil design and powder size effects are discussed. For Solder on Pad, stencil design and pad finish effects are discovered. For BGA balls attach, the ability to reduce final package coplanarity is disclosed using solder paste. For System in Package, guidelines for paste printing 01005 chips are discussed. Quantitative data on material printability, dip-ability and pin transfer efficiency are covered in detail. Guidelines for suitable powder sizes for various applications are provided. Powder types from 5 through 8 are described and compared for various application processes as well as stencil and pin transfer tool designs.

Introduction
Solder continues to be the most reliable and cost effective electronic assembly material. This holds true in both the SMT and semiconductor packaging markets. As the electronics industry completes the conversion to lead free solders, solder pastes are proving more cost effective than plated up solders especially when dealing with tertiary, quaternary and dopant level alloys. Mostly driven by the hand held product sector, solder connections continue to shrink in size. They also increase in number to support the expanding features of these products. These two technology trends have accelerated the applications requiring solder pastes with powder types smaller than type 4. The conventional method for producing these fine powders was to simply extend the same sieving technology to sort the powder steam for finer powders. This method results in high production costs and damaged powder. These conventional powder formation methods in inert gas also produce poor powder morphology as can be seen in Figures 1 & 2. New proprietary technology has met this deficiency yielding high quality, extremely spherical fine solder powders up to type 9 currently (Figure 3).

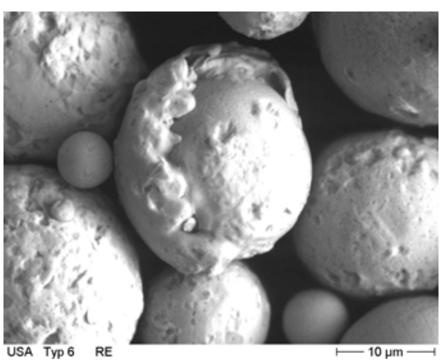

Figure 1 Supplier A, Type 6

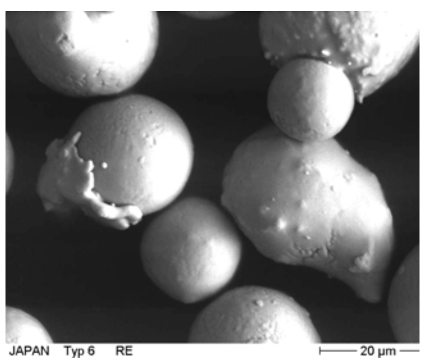

Figure 2 Supplier B, Type 6

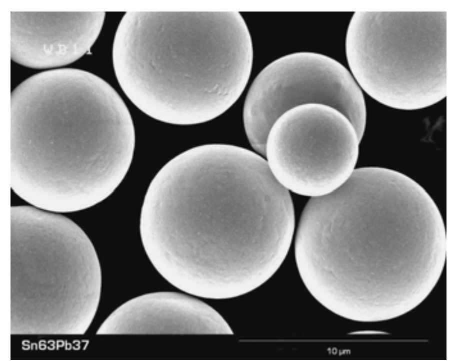

Figure 3 Welco Process, Type 6

Wafer Bumping
Wafer bumping using solder paste can be done by two different processes. One process is proprietary and involves printing directly onto a wafer with dry film over the bump side of the wafer. Blind holes in the dry film are formed photo lithographically with the UBM (Under Bump Metallization) at the base of the hole. This process is capable of producing high bump height to pitch ratios at pitches at or below 70µ[1]. Fine powder solder paste is printed multiple times to completely fill the blind dry film hole and reflowed in an inert atmosphere. The dry film resist is then stripped off of the wafer, the bumps are then fluxed and reflowed a second time to form their final compressed truncated spherical shape.

The other process uses a thin typically electroformed nickel stencil to print directly onto the wafer surface. Fine powder solder paste is usually overprinted over the UBM, reflowed in an inert atmosphere and cleaned. For full grid arrays round or square apertures are used, for staggered or perimeter arrays ovals or rectangular apertures can be used to increase the bump height to pitch ratio. Current pitches that are capable of being bumped with this process are limited to 125 micron pitch and larger. Stencil fab technology is predominantly electroformed nickel in the 1-3 mil thickness range. Final bump formation is achieved by reflow in a convection oven in low O_2 nitrogen, typically in the 10-20 ppm range. Post reflow flux residues are removed by cleaning with chemistries matched to the flux formulation. Most paste formulations for wafer bumping are water soluble to facilitate flux removal with simple aqueous cleaners. Solder powders are typically type 5 (15-25µ) and type 6 (5-15µ) and available in a variety of alloys to suit the application although new finer powders up to type 9 have now become commercialized. The challenge in this process is producing high bump to pitch ratios that are typical of plated up bump technology. For a 50 micron stencil with type 6 powder, bump height to pitch ratios of 0.37 to 0.41 were achieved for full bump arrays in the 150µ to 250µ pitch range[2]. In this study round apertures generally yielded higher ratios than did square apertures.

In an internal study on a 200mm test wafer with type 6 powder[3], squeegee material effects were tested for bump consistency. High durometer polyurethane and electroformed nickel squeegee materials were compared and contrasted for a pitch range of 100µ to 1mm. As can be seen in Figure 4, the polyurethane squeegee enabled good coplanarity down to 125µ but gave very large bump height distributions at the pitches larger than 250µ. This was proven to be from scooping in the larger apertures at the larger pitches. The nickel blade simply prevented this but was less ideal for the fine pitches. It is thought that the polyurethane squeegee provided some "pumping" action in very small apertures that are typical of fine pitch full arrays.

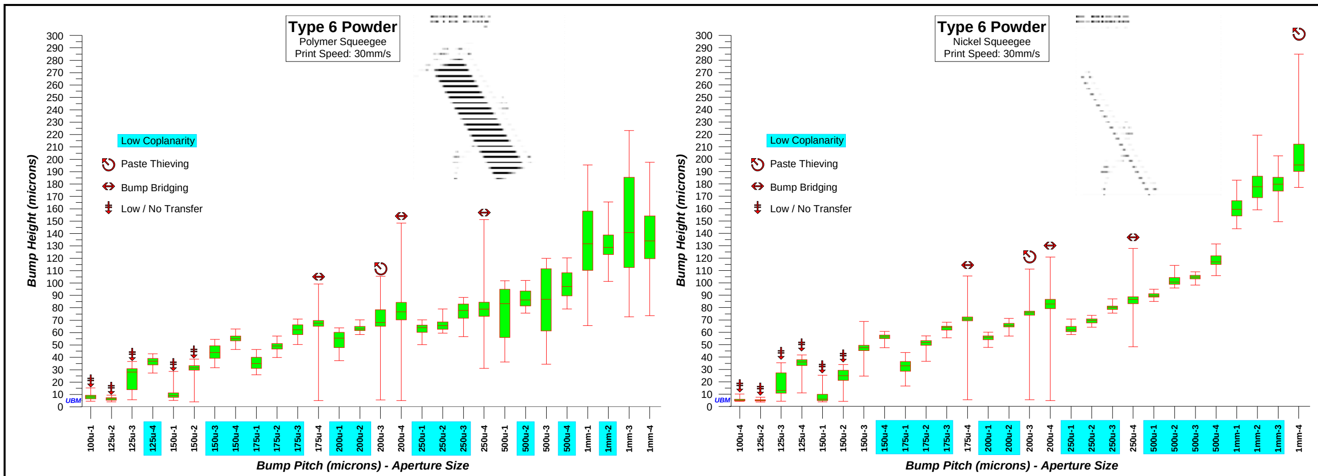

Figure 4 Squeegee Material Effects

A recent study comparing the effects of powder size for pitches in the range of 125µ to 250µ revealed a moderate bump height increase due to finer powder size as can be seen in Figure 5. This was related to simply getting more metal into these small apertures during the aperture fill portion of the print process. Powder types 5, 6, 7 and 8 were compared with the same wafer as in the squeegee comparison. To verify this, an older wafer bump test stencil was printed with two equal solids and viscosity solder pastes of the two fine powder extremes (type 5 & type 8). Printed solder volumes (2500 of each paste) were measured across the wafers and plotted as a distribution. As can be seen in Figure 6, the finer type 8 powder yielded not only a significantly tighter distribution of volumes but a larger median volume, confirming the earlier work on bump height.

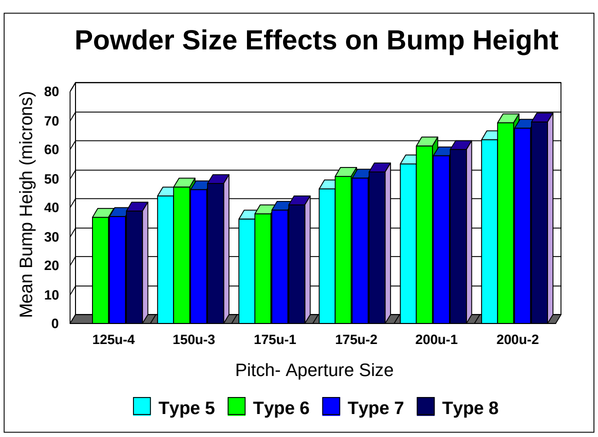

Figure 5 Finer Powder for Higher Bump Height

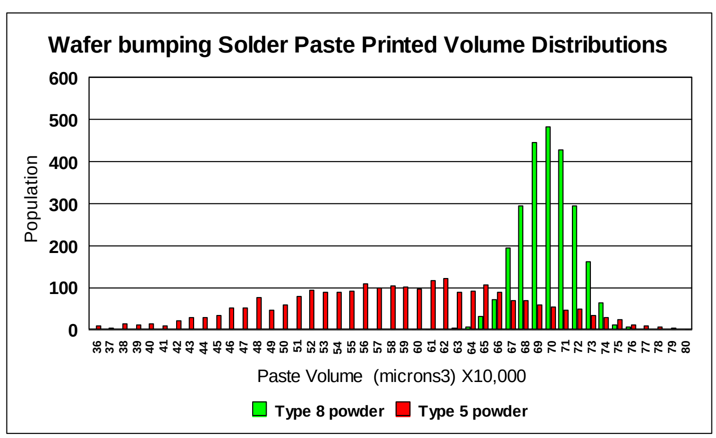

Figure 6 Finer Powder Yields Tighter Distributions

Table 1 Powder Classification per *J-STD-005*

Type	No Larger Than	Less than 1% are larger than	At least 80% are between	**No more than 10% are smaller than**
1	160µ	150µ	150µ up to 75µ	**20µ**
2	80µ	75µ	75µ up to 45µ	**20µ**
3	50µ	45µ	45µ up to 25µ	**20µ**
4	40µ	38µ	38µ up to 20µ	**20µ**
5	30µ	25µ	90% min 25µ up to 10µ	**10µ**
6	20µ	15µ	90% min 15µ up to 5µ	**5µ**
7	15µ	11µ	90% min 11µ up to 2µ	**Maximal 1% > 2µ**
8	**11µ**	**10µ**	**8µ up to 2µ**	

System in Package (SiP)

SiP applications for fine powder solder pastes are mainly type 4 and 5 for 0201 and 01005 chips respectively. These are typically water wash formulations because the package is typically over-molded before singulation from the array. Figure 7 shows a typical SiP package before encapsulation. Powder size specification for a 01005 application should follow the five-solder-ball rule[4]. To apply this rule we must consider the maximum powder size in the fourth column in Table 1 and a extreme small example of a 170µ x 180µ 01005 aperture as is shown in Figure 8.

Figure 7 System in Package

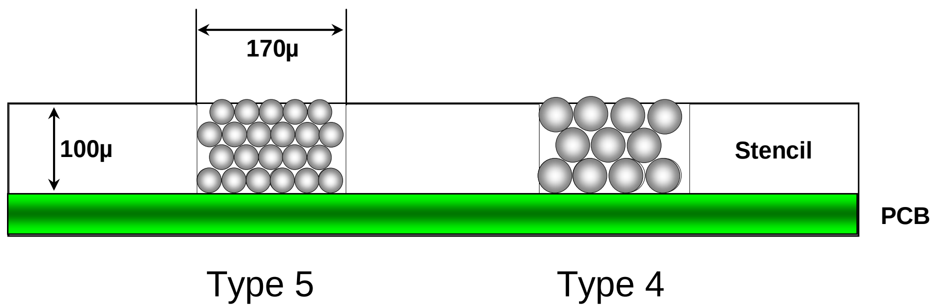

Figure 8 01005 Stencil Aperture Dictates powder Size

All of the good practice rules in SMT need to be closely followed in printing these very small deposits. Apertures need to be slightly smaller than the solder pad for proper stencil gasketing, good board support should be available and solder pastes should be selected for minimal hot slump to prevent beading or shorts. If using a type 5 or smaller powder, nitrogen reflow should be considered due to the high surface area that accompanies fine powders, especially if the flux system is a no clean to minimize solder balling.

Solder on Pad (SoP)

Solder on pad is one of the growing solder pad finishes for flip chip and BGA assembly. SoP technology has proved to be a better option in terms of reliability because of the higher standoff height, than the conventional Ni/Au or OSP pad surface finishes used for flip chip substrates. SoP also assures pad solderability much in the same way that HASL has done for years in SMT level 2 assemblies. Typically this is accomplished with solder paste printed through a thin stencil onto the ball attach or flip chip attach solder pad on a laminate substrate. Paste is reflowed and residues are then cleaned. Requirements for solder height vary as well as the height reference point. Most applications are lead free currently. One universal requirement is for full pad coverage of solder. Pad designs are circular but size varies from supplier to supplier as well as due to pad pitch. This process is typically done at the laminate supplier. In many cases the height of solder is referenced to the solder mask[5] as can be seen in Figure 9.

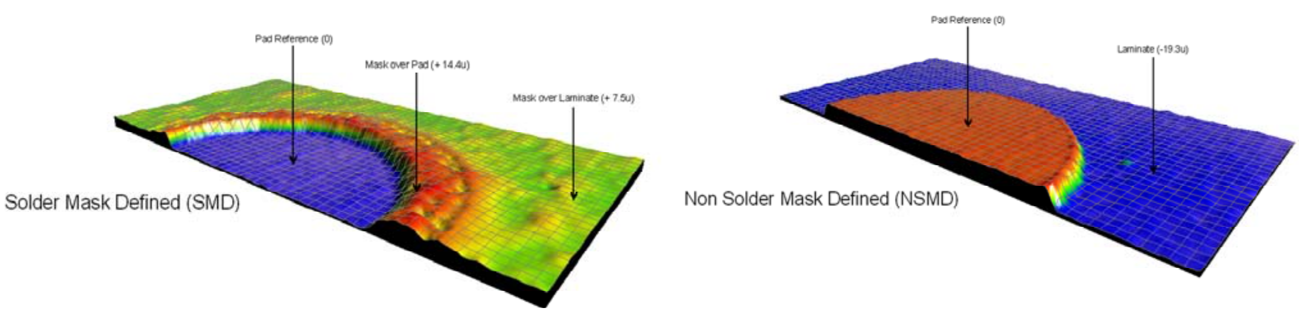

Figure 9 SoP Height Relative to Mask and Laminate Locations

In an internal study to better understand the solder paste attributes that are key to SoP, pitches of 1.0mm, 0.8mm and 0.5mm were studied. Variables in this study included, pad finish (OSP and ENIG), pad definition (mask defined and not solder mask defined), stencil thickness (25µ, 50µ and 75µ) and aperture size (55% up to 110% pad diameter). Only lead free solder (SAC) was used in this study. Reflow was done in nitrogen with an O^2 level of 15-20 ppm. Immediately after reflow the boards were cleaned in an in-line impinging spray cleaner using DI water at 135ºF @ 60PSI with a belt speed of 3 fpm. After cleaning, boards were stacked with lint free wipers separating them to prevent any marring of the SoP surface prior to measurement. Measurement was done with a confocal measuring system with a height resolution of 10 nanometers. All measurements were taken relative to the pad surface. Following measurement, SoP test grids were inspected for 100% coverage of solder visually. Only data from 100% wetted pads was considered acceptable.

The first observation worthy of note is the need for fine powder paste formulations with thin stencil applications such as SoP. This is most noticeable to the naked eye on paste prints with thinner stencils. Figure 10 is a photograph of a NSMD pad that is overprinted using a 25 micron thick stencil. In some areas there is as little as one particle of type 5 powder on the pad surface. Figure 11 is the same stencil, aperture size and print process with an SMD pad. The second observation as due to the significant wetting differences of copper as compared to ENIG. There was much more print registration sensitivity when using copper as a solderable surface. The wetting angle chart in Figure 12 shows that this metallurgical trend is amplified when using a SAC Lead Free alloy as opposed to tin/lead as was done in this study. The higher the wetting angle, the lower the wettability. As can be seen in the 50 micron stencil data in Figure 13, the ENIG process window is nearly the complete test matrix with the exception of the smallest aperture on the smallest pitch over NSMD pads. This was most likely due to paste release and not wetting. With thick enough stencils substrate bumping (SoP taller than mask) can be achieved.

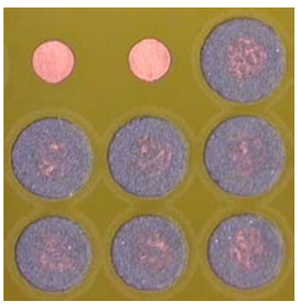

Figure 10 NSMD

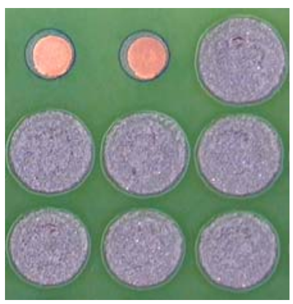

Figure 11 SMD

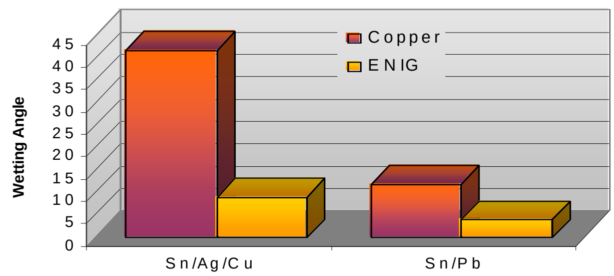

Figure 12 Pad Surface Metallurgy Wetting

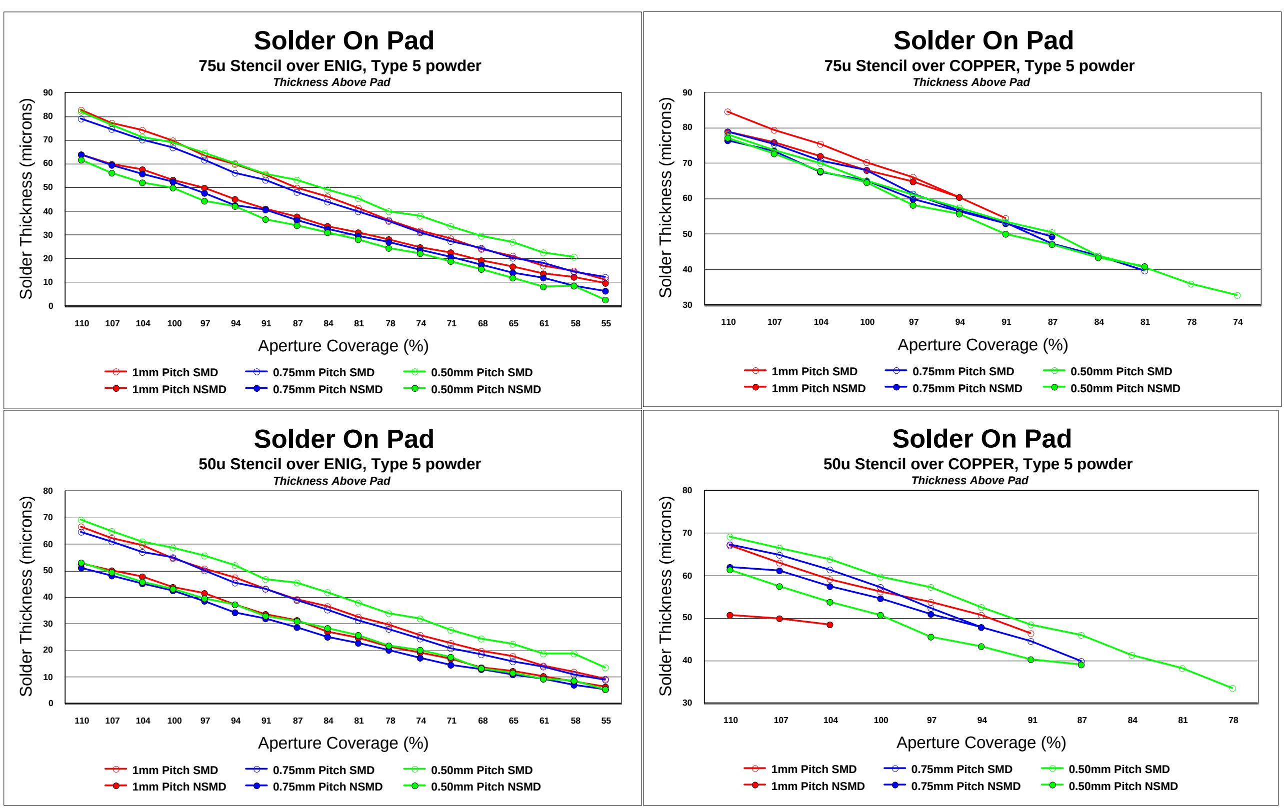

Figure 13 SoP Heights Obtained

BGA Ball Attach

Of the numerous methods to attach solder spheres to BGA packages, several involve fine solder powder applications. The first method is simply printing solder paste through a 50 micron thick stencil. Apertures are usually round and very close in size to the solder pad diameter. For this stencil thickness a type 4 powder would be sufficient but as in our SoP study, thinner stencils would require smaller powder.

Since all PBGA's have some degree of coplanarity, a novel stencil aperture layout has been proposed[6] to reduce this undesirable attribute. The current "box" of thought on ball attachment boils down to everything being as equal as possible. Solder ball diameter and volume, solder paste volume, Solder on Pad height and volume, are desired to be as equal within a package as possible. Following this logic will yield a very coplanar grid of balls if the underlying substrate is also coplanar. This, however, is not the case as packages are warped to some degree. Warpage stems from die or flip chip attach, underfill and molding processes that preclude the ball attach process. Although some advances in materials have helped to reduce warpage, technological pressures such as thinner laminates and die have eroded these benefits resulting in basically very little warpage improvement of BGA's since their implementation. If having the balls and the attach material deposits being equal is the current thinking inside the box, then the opposite is clearly thinking outside of the box. The first step is to fully understand the final package warpage as measured at the ball apex. This, essentially, is the coplanarity that the level 2 assembler will see. In an array of BGA's on a strip it will likely vary with the position of the device in the array and possibly the array position on the strip. There will also be package to package variability of warpage. The recommendation is to address the nominal package warpage for every package site. Addressing the average warpage topography of a statistically significant package population is recommended. This concept will only reduce the coplanarity, not eliminate it, but a reduction of even 25µ can be significant in some packages. Predicted coplanarity reduction for a 1mm pitch package is charted in Figure 14. After the "nominal" final warpage topology has been established, a starting stencil design would simply include the following as illustrated in Figure 15:

- At sites closest to the seating plane use an aperture diameter equal to the pad diameter. This will ensure complete wetting on the pads with the least amount of solder paste even when copper OSP is the pad finish.
- At sites farthest from the seating plane use an aperture that is twice the pad diameter of the solder pad. This is where the largest final reflow ball diameter is desired. For fine pitch BGA's and/or thicker stencils, a good guideline is that the "webbing" between the apertures should be ≥ 0.8 times the stencil thickness. If the paste used has some slump properties it may be necessary to further reduce the largest aperture diameters to prevent shorting.
- For all other aperture sites, the warpage scenario should dictate the aperture diameter trend. For a constant radius warpage, use a simple equidistant mathematical ladder of sizes.

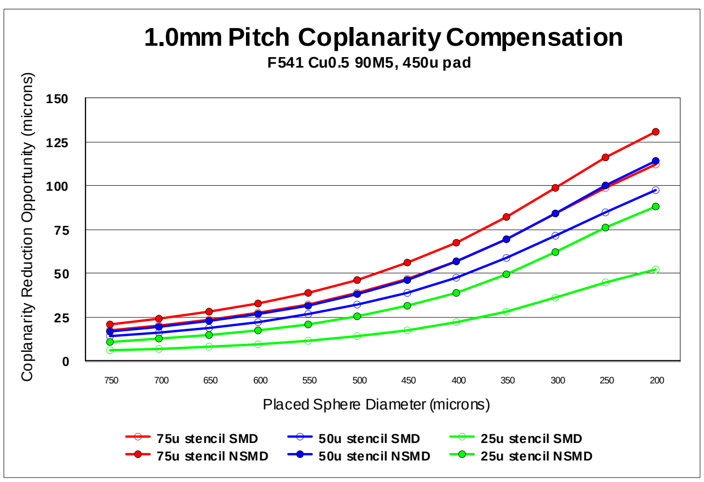

Figure 14 Coplanarity Reduction Trends

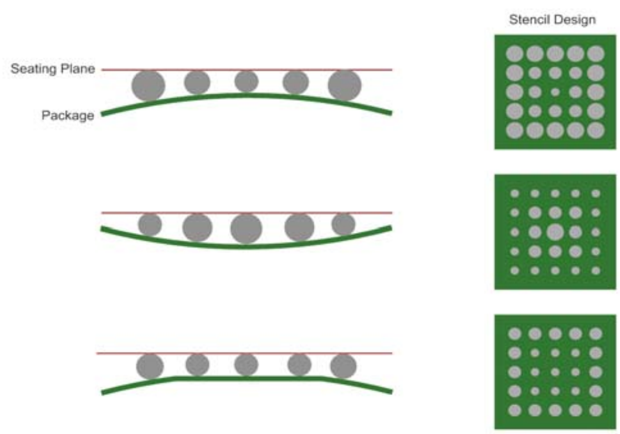

Figure 15 Various Implementation Designs

A newer method of BGA sphere attach that has demonstrated significantly reduced ball short defects on SoP surfaces, involves the use of a dippable paste. This reduced solids formulation is designed to replace standard tacky flux when flux dipping precedes sphere drop. These pastes typically utilize type 5 and 6 powder of the same alloy as the solder sphere. The spheres are typically dipped about a third of their diameter as in Figure 16. The tiny particles of solder keep the sphere from moving after placement due to transfer forces or convection forces in the reflow. The result is a significant ball attach process first pass yield improvement. Cross sections have showed[7] that there was complete miscibility of metal powder and the solder balls. The intermetallic thickness for immersion Sn, SoP and OSP, were comparable to a flux only process at 3µ. The copper consumption measured on OSP was 4-5µ. For BGA applications these formulations are water washable, which permits aggressive flux chemistries that are required for robust wetting to OSP, immersion Sn and lead free finishes.

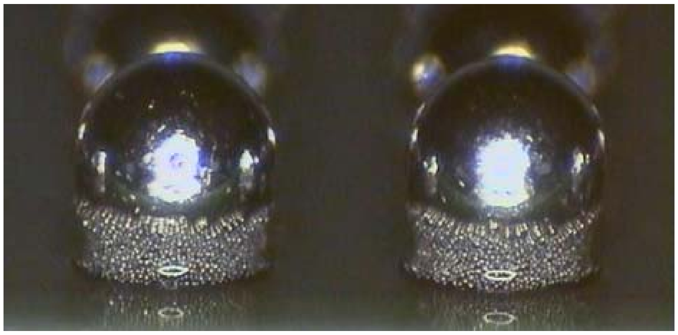

Figure 16 Ball Dip (*Courtesy of TI*)

Figure 17 Pin Transfer (*Courtesy of Amkor*)

Another application for these dippable solder pastes is again as a ball movement yield improvement material, but for process equipment that uses pin transfer tooling. Instead of directly dipping the solder spheres into the attachment media (dippable paste or tacky flux), an array of pins dips then “stamps” the BGA laminate before the spheres are dropped as can be seen in Figure 17. This then creates a need for the material supplier to understand the “pin transferability” of a material. This would be the materials ability the transfer a consistent volume and diameter over time. To develop the in-house capability of measuring the transfer capability of dippable materials, a tooling strategy was sought to include physical elements of both spheres and flat ended posts or pins. In researching available pins, only electrical test “pogo” pins turned up in the desired range of sizes that are common in pin transfer and BGA spheres. One of the leading companies that make these pogo test pins was contracted to build a block of 50 pins of 5 different sizes and end shapes for our initial evaluations. The dip reservoir was designed to have a lockable base that can be shimmed to yield a precise dip depth. An adhesive dispenser provided an excellent available automation framework for a dipping operation in that it is simply a 3-axis robot by design. The integrated touch height sensor helped provide Z axis repeatability for the process. This setup can be seen in Figures 18 and 19. Stamping and measurement was done on float glass due to its smooth and flat surface. Figure 20 show typical pin loading for various pin diameter and end shapes. The 50th dip trend charts in Figure 21 showed that transferred volume is fairly equal for the medium and high solids materials. As solids is increased in the BD41, the deposit diameter decreases, the deposit heights increase yielding higher deposit aspect ratios[8] (3D shape factor).

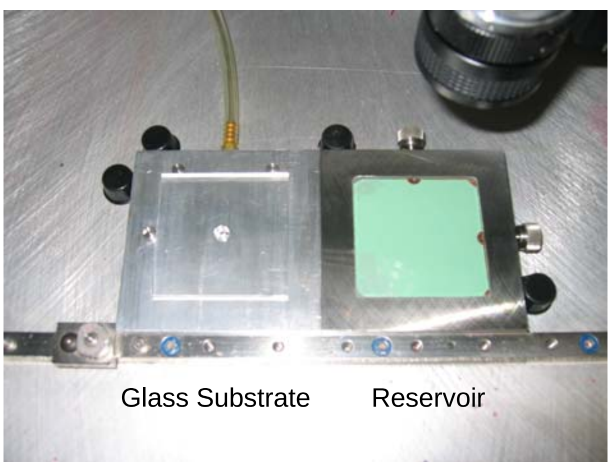

Figure 18 Transfer Glass & Reservoir

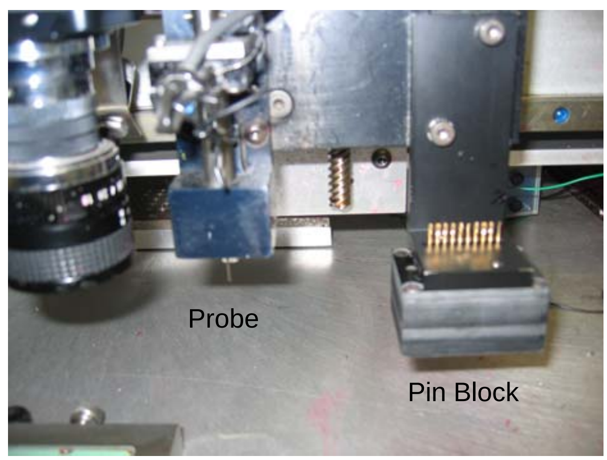

Figure 19 Height Probe and Pin Block

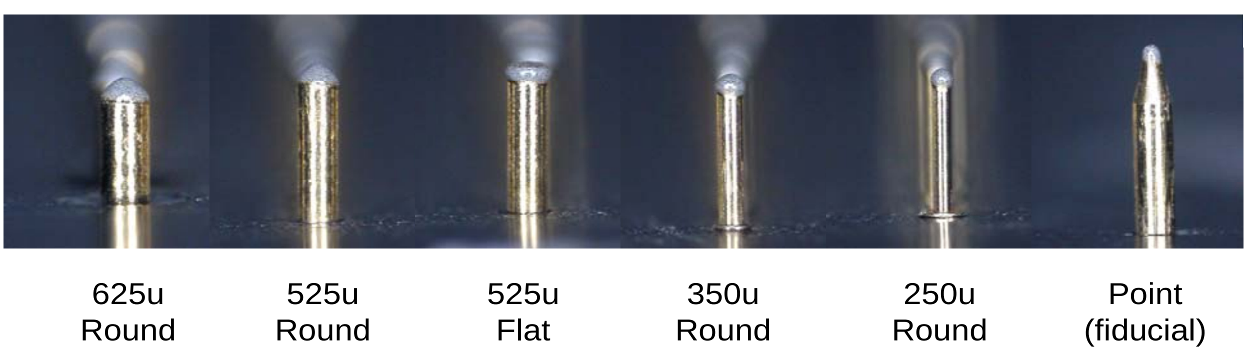

Figure 20 Typical Pin Loading

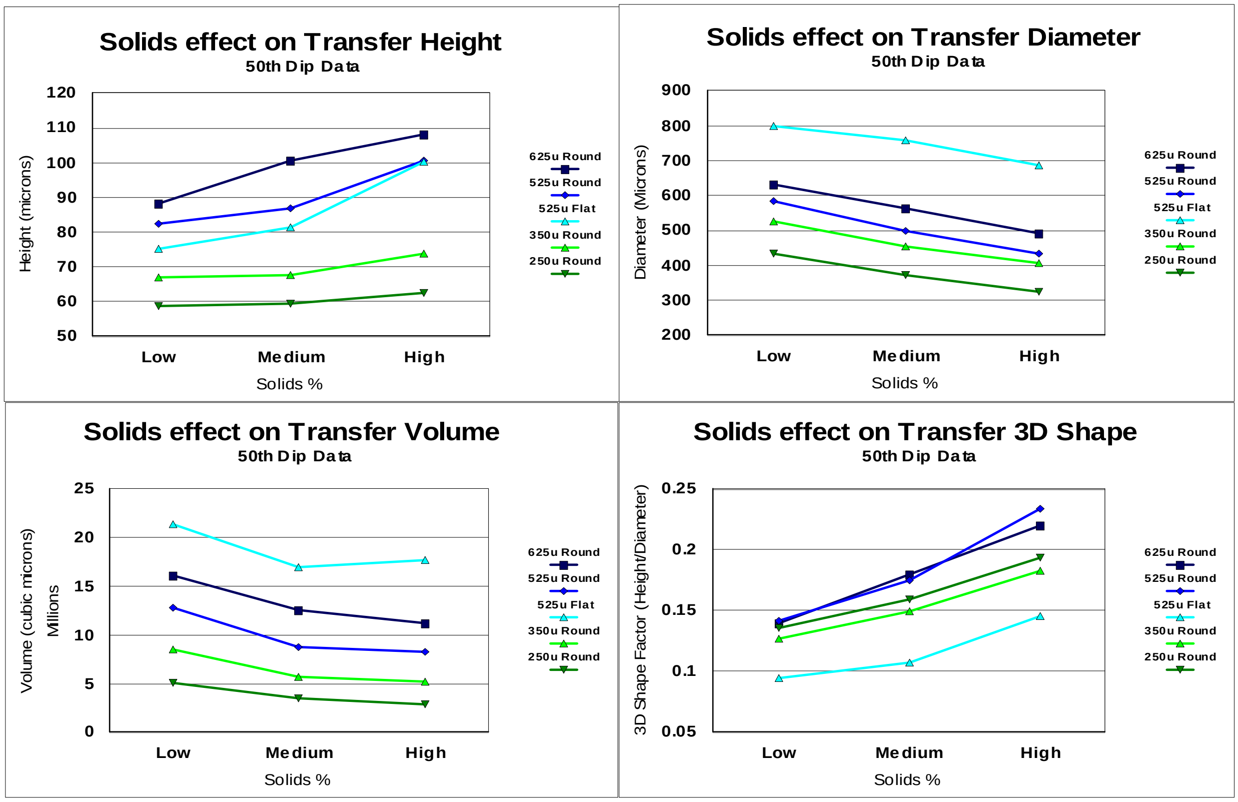

Figure 21 Pin Transfer Trends

Conclusions

- For wafer bumping using the overprint UBM method, bump height to pitch ratios are possible in the range of 0.37 to 0.41. Round apertures are more efficient than rectilinear ones.
- Wafer bumping with large apertures is best accomplished with metal blade squeegee while high durometer polymer squeegees enable printing very small apertures by providing some pumping action for fine pitch (<250u).
- Finer powders increase bump height moderately and yield tighter paste volume distributions during printing.
- By following the five-solder-ball rule, printing 01005 stencil apertures is best accomplished with paste formulated with type 5 powder.
- Solder on Pad can be accomplished using thin stencils and pastes formulated with fine powders. The height of the solder deposit can vary from lower than the mask height to bumps depending on the final application. ENIG pad finish offers the largest process capability window for SoP.
- For BGA ball attach, package coplanarity can be reduced using a variable aperture size stencil design. Thin stencils require the use of pastes formulated with fine powders to provide adequate print density.
- Dippable solder pastes can provide relief from ball short defects by replacing tacky flux. These materials can either be applied directly to the solder spheres or via pin transfer methods.

References

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Heraeus

Fine Powder Solder Paste Applications for Semiconductor Packaging

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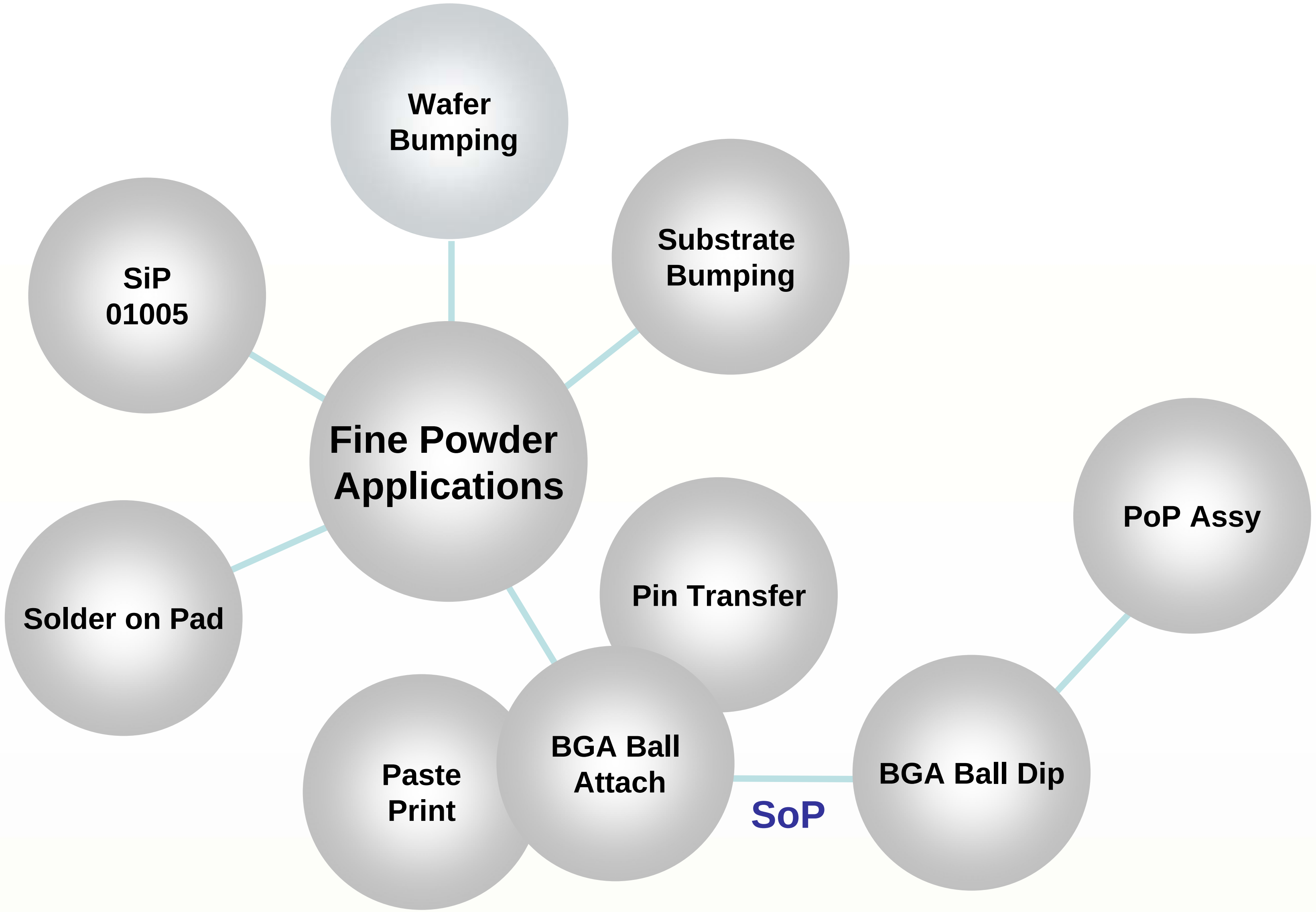
Wafer Bumping
SiP 01005
Substrate Bumping
Fine Powder Applications
PoP Assy
Pin Transfer
Solder on Pad
BGA Ball Attach
Paste Print
SoP
BGA Ball Dip

Powder Size Specifications

Type	No >	Less than 1% are >	At least 80% are between	No more than 10% are <
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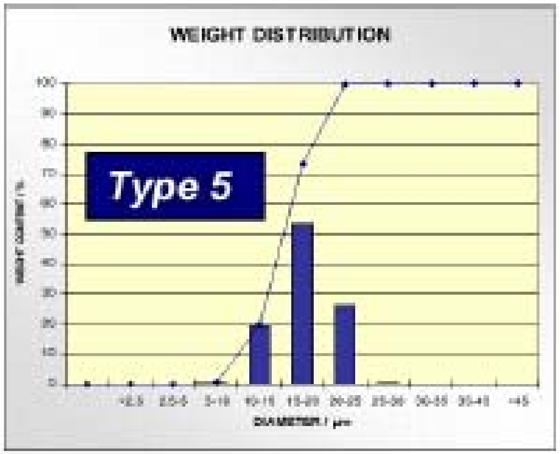
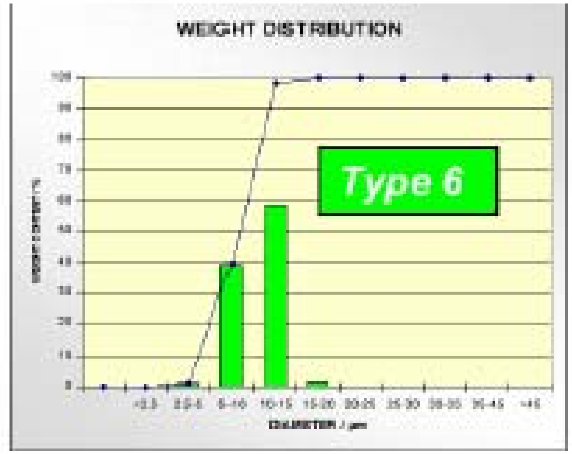
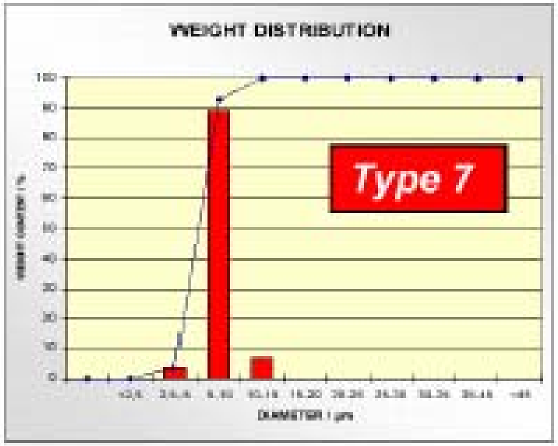
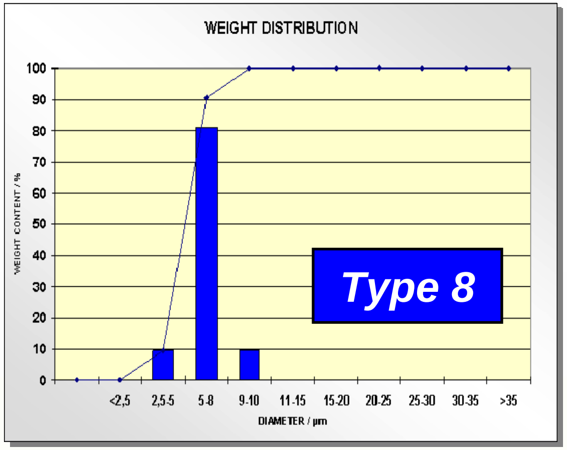
7	15µ	11µ	90% min 11µ up to 2µ	Maximal 1% > 2µ
8	11µ	10µ	8µ up to 2µ	

Powder Particle Size Distributions

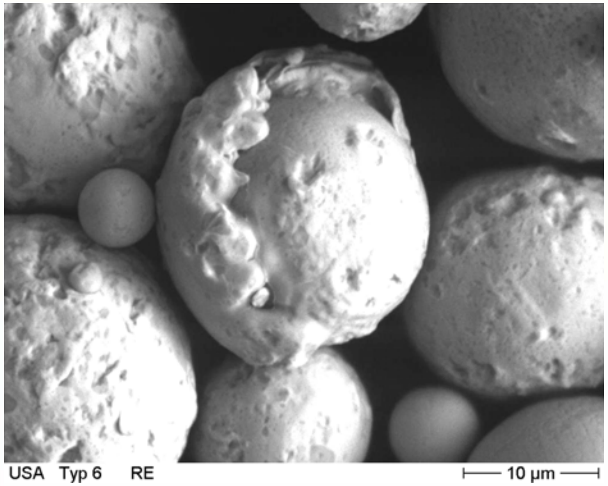




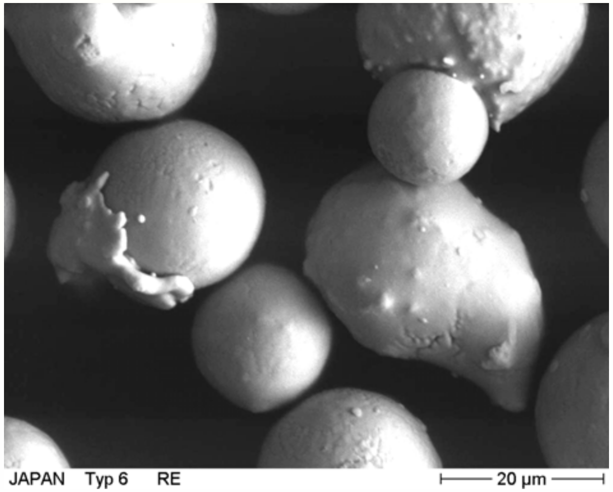




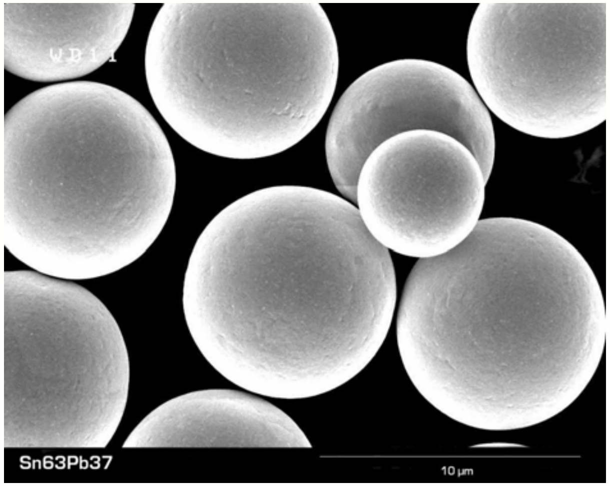
Type 6 Powder Quality



Supplier A

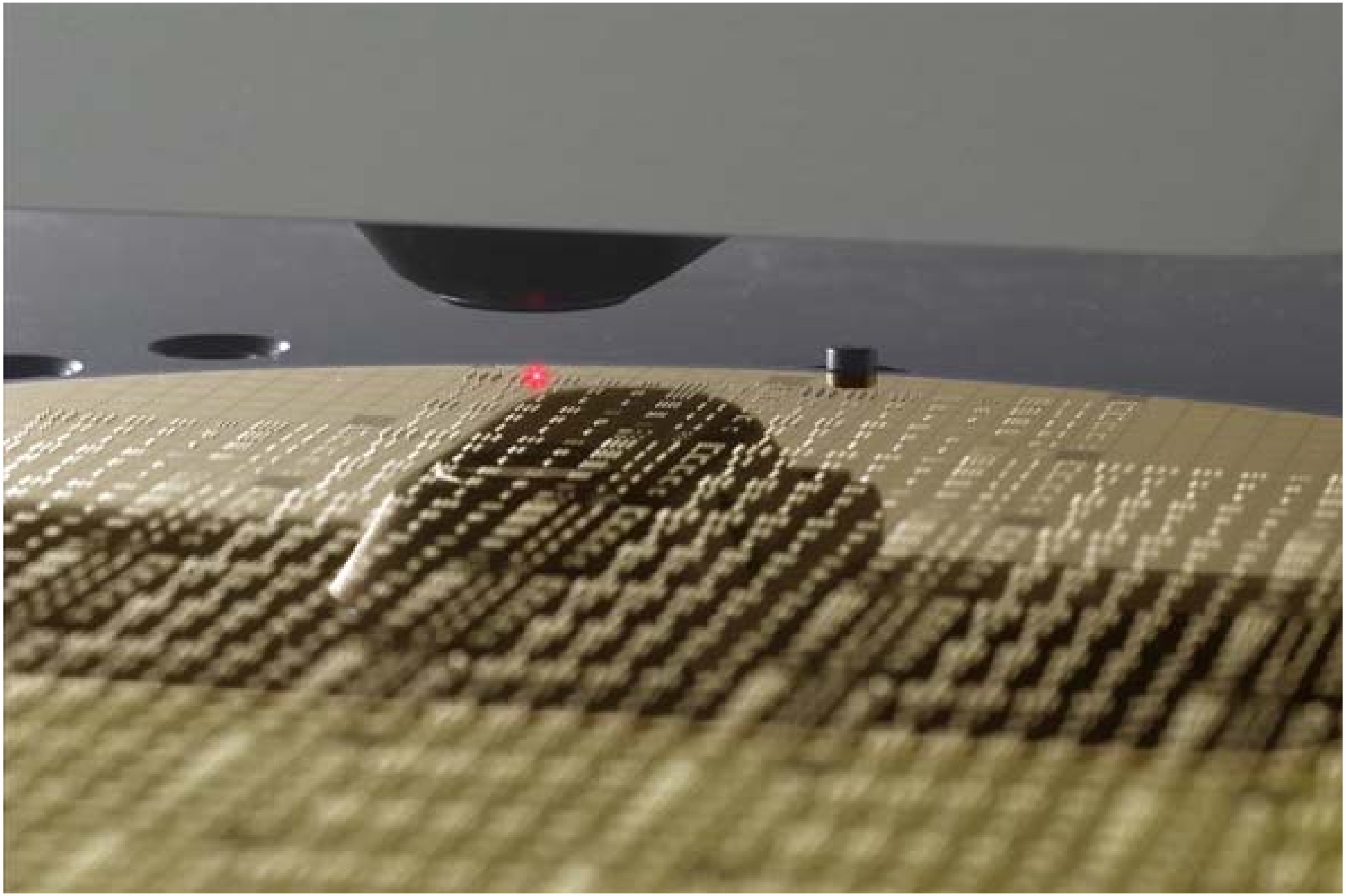


Supplier B

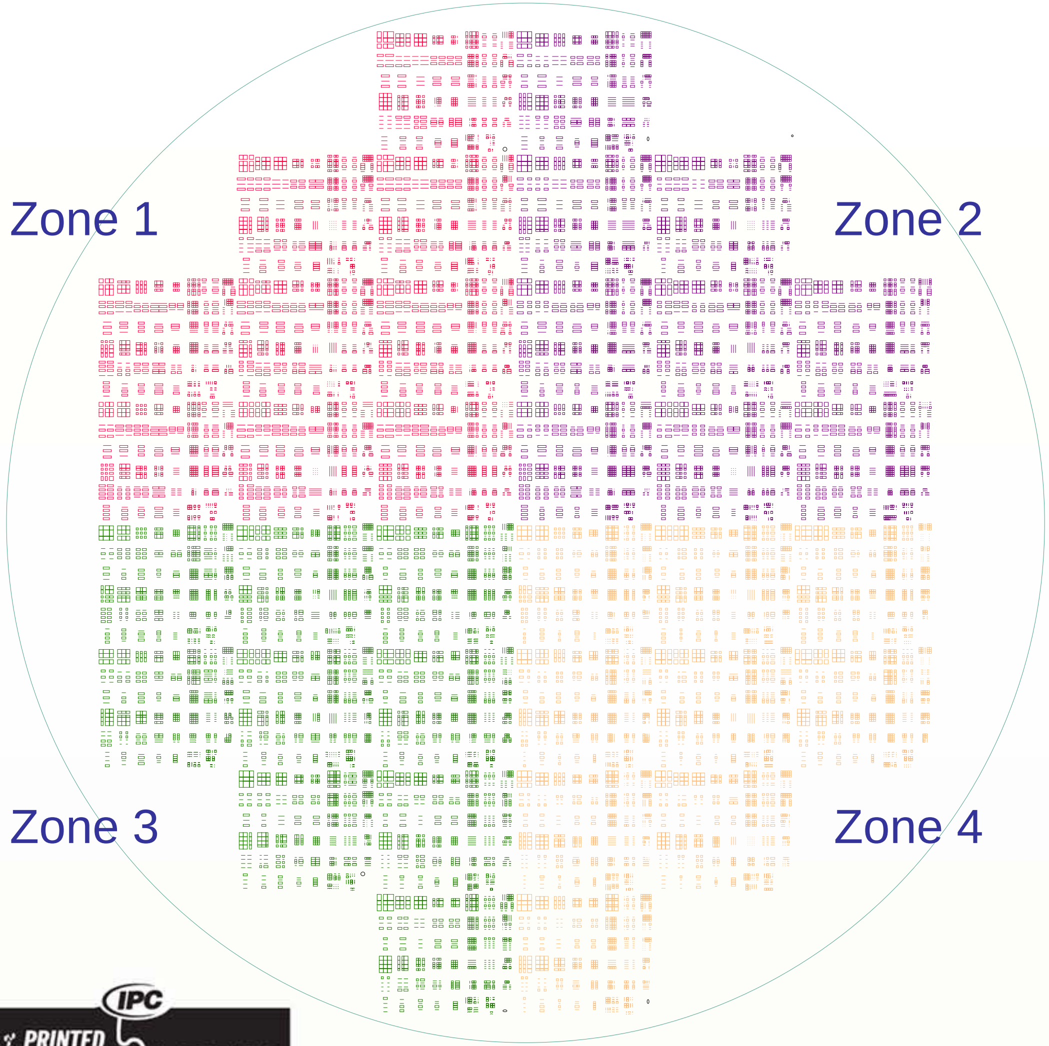


Welco Process

Wafer Bumping (Stencil Overprinting UBM)



200mm Test Wafer

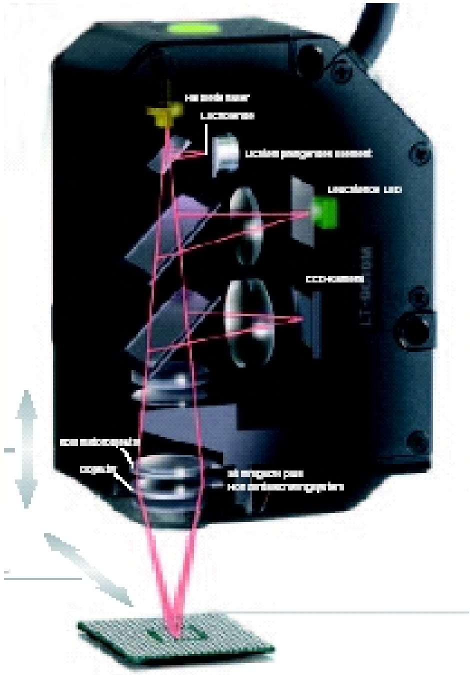


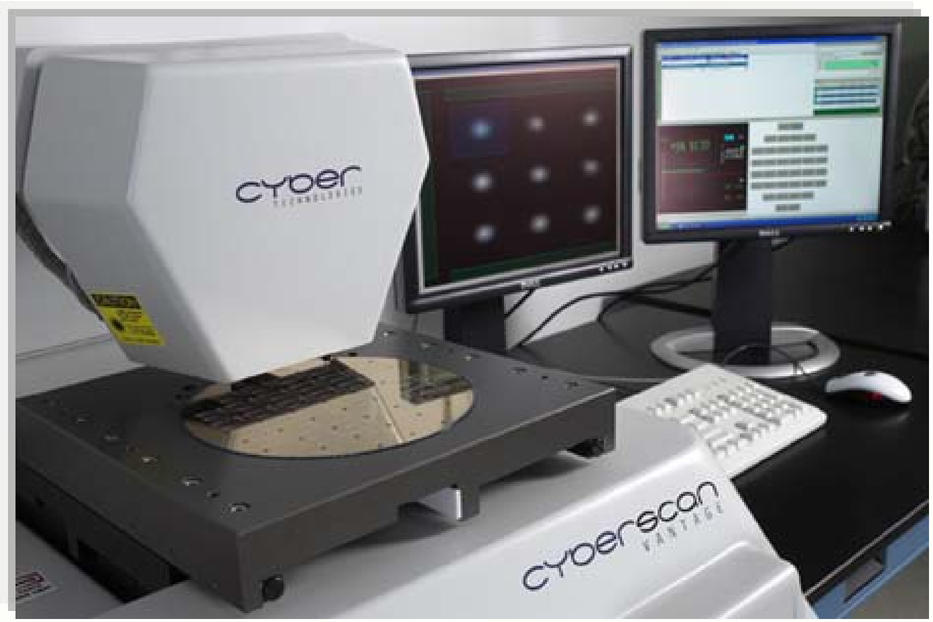
Stencil Aperture Sizes

Pitch	Zone 1	Zone 2	Zone 3	Zone 4
1mm	**848µ**	**874µ**	**901µ**	**924µ**
500µ	**348µ**	**374µ**	**401µ**	**424µ**
250µ	**161µ**	**176µ**	**192µ**	**206µ**
200µ	**111µ**	**126µ**	**142µ**	**156µ**
175µ	**86µ**	**101µ**	**117µ**	**131µ**
150µ	**61µ**	**76µ**	**92µ**	**106µ**
125µ	**NA**	**51µ**	**67µ**	**81µ**
100µ	**NA**	**NA**	**NA**	**56µ**

Confocal Measuring System

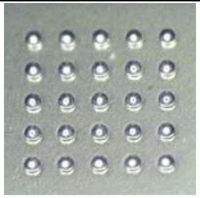
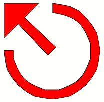
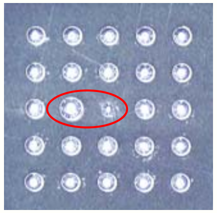
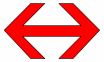
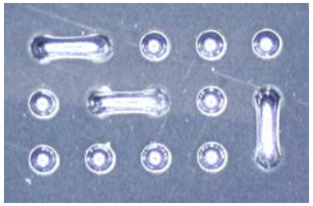
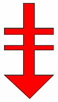
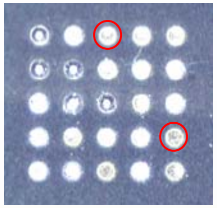
- Range:
  - 600 microns (Z)
  - 200mm (X,Y)
- Z resolution: 10 nanometers
- X-Y resolution: 100 nanometers



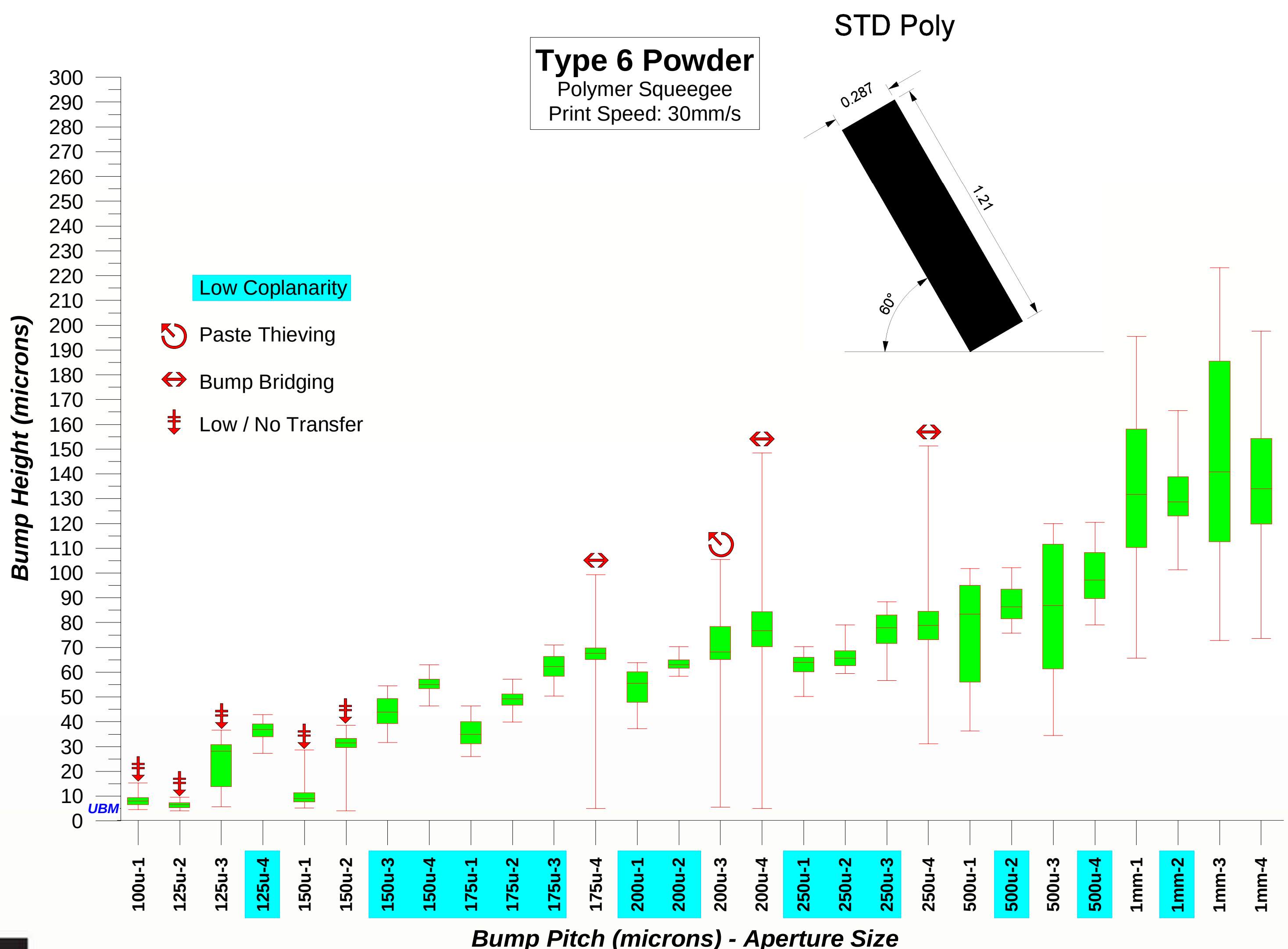


Test Wafer Mini Study – Squeegee Effects

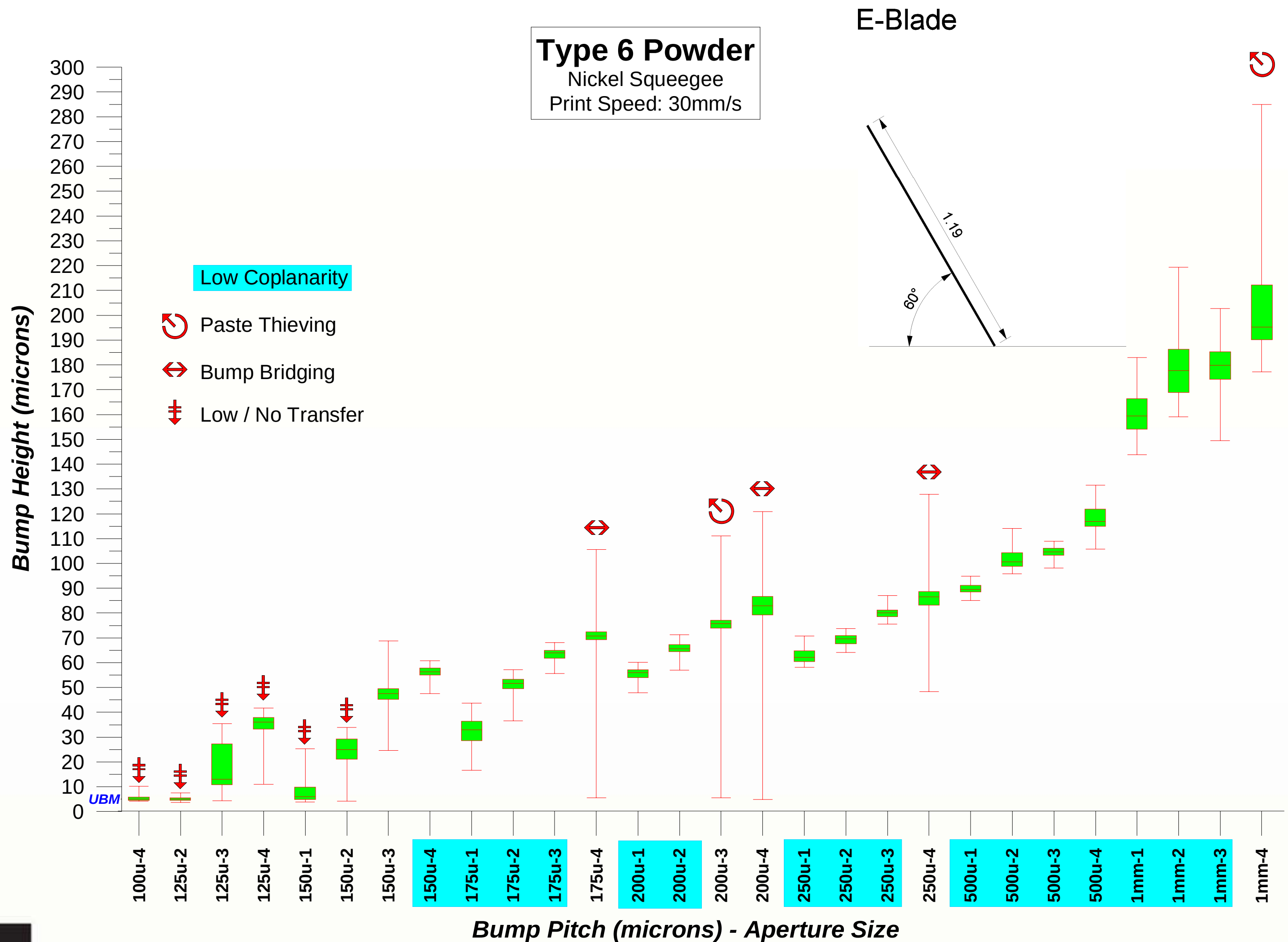
- F510Cu0.5 90H6 (SAC405 LF , type 6 powder)
- 40μ thick E-Fab® electroformed nickel stencil
- Print Process
  - 30mm/s print speed
  - 0.1mm/s separation speed for 2mm
  - 4-5kg pressure
- Squeegee (250mm)
  - 95 durometer polymer trailing edge @ 60° (5kg)
  - E-Blade® electroformed nickel (4kg)
- 19,000 bumps measured for mini study

Attribute	Chart Symbol	Example
Good - Low Coplanarity		
Defect - Paste Thieving		
Defect – Bump Bridging		
Defect – Low/No Transfer		

Polymer Squeegee Effects



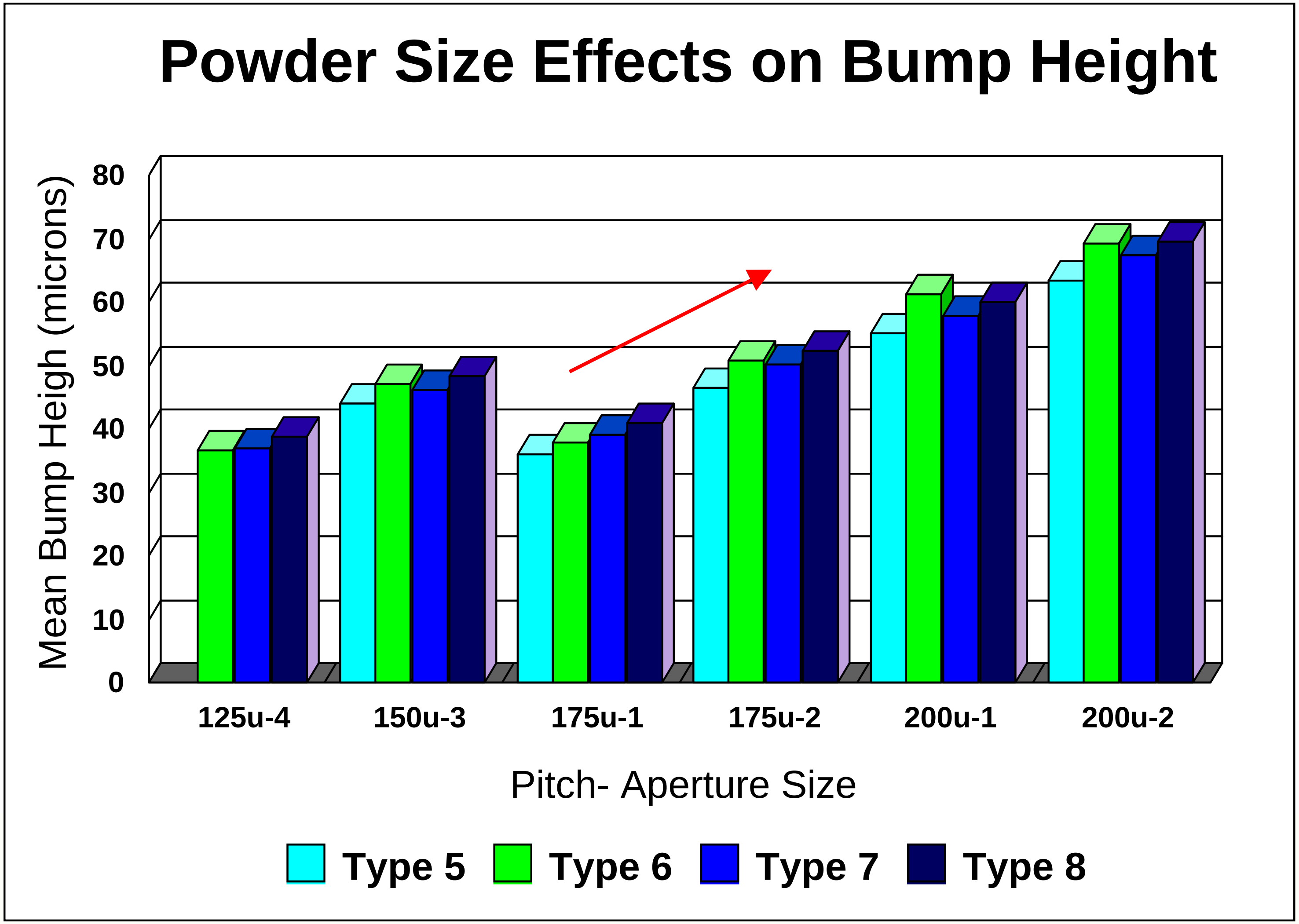
Nickel Squeegee Effects



Test Wafer Mini Study – Powder Size Effects

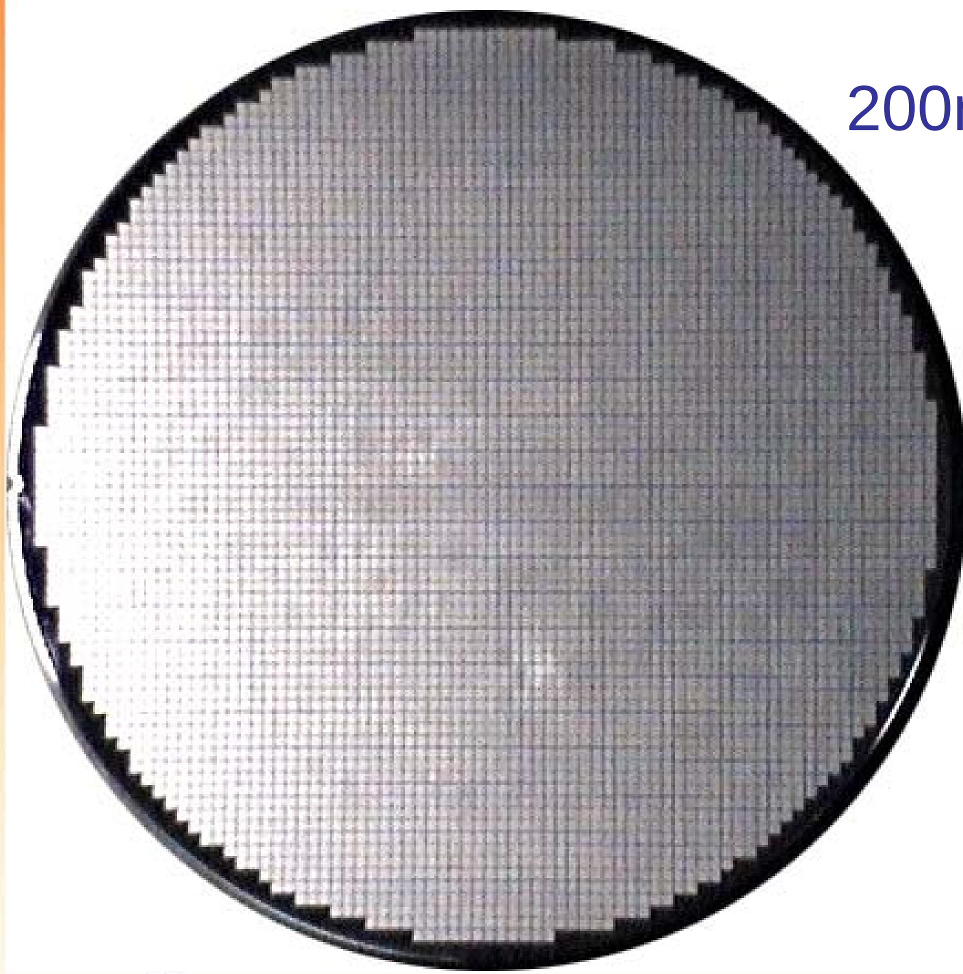
- Four F510 Lead Free (SAC405) pastes
  - Solids and viscosity kept constant
  - Powder Types varied - 5, 6, 7 & 8
- Polymer squeegee used
- Slow print speed
  - 10mm/s
- Slow separation speed
  - 0.1mm/s
- 200μ, 175μ, 150μ, 125μ & 100μ pitches measured
  - 32,400 bumps measured for mini study

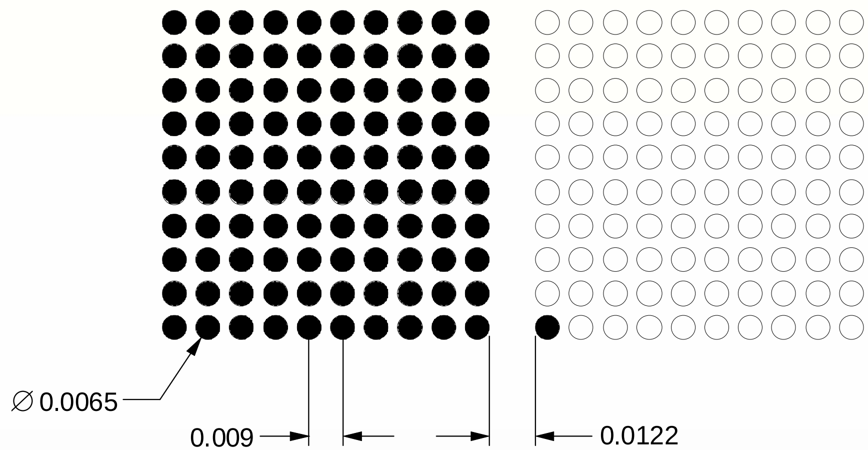
Mini Study – Powder Size Effects



Solder Volume Comparison

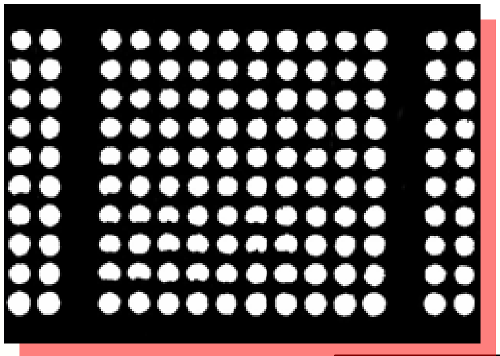
200mm Wafer



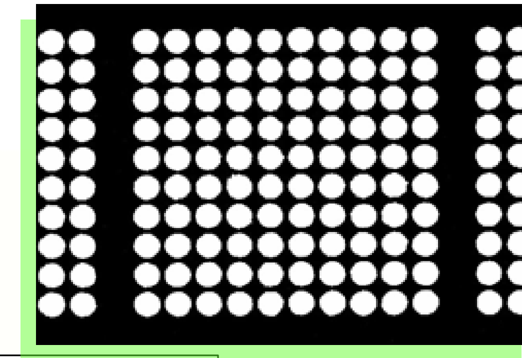


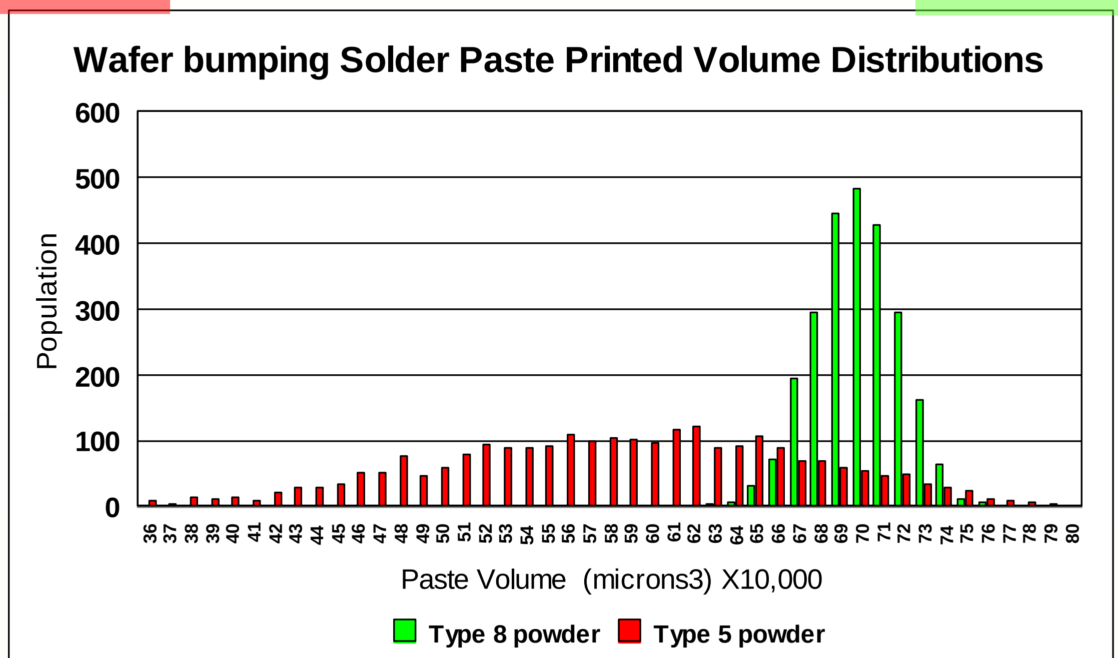
453,000 Apertures

Type 5 Vs Type 8 Printed Volume Comparisons

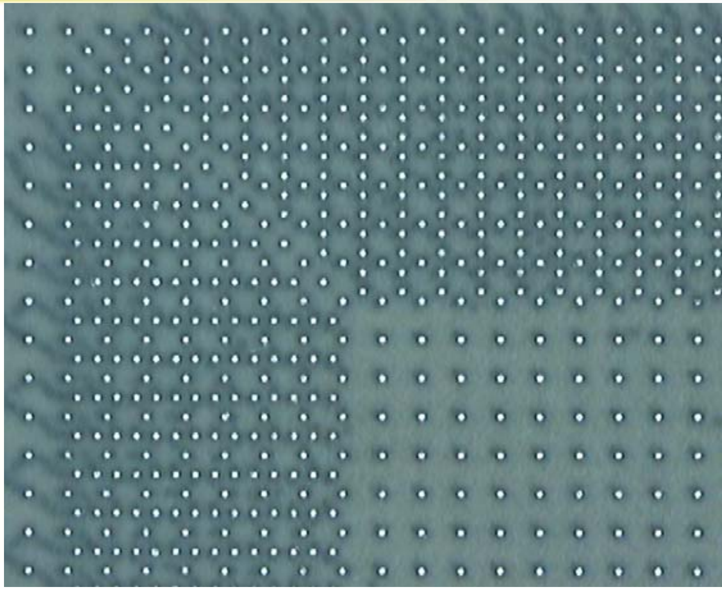


2500 deposits measured
for each paste



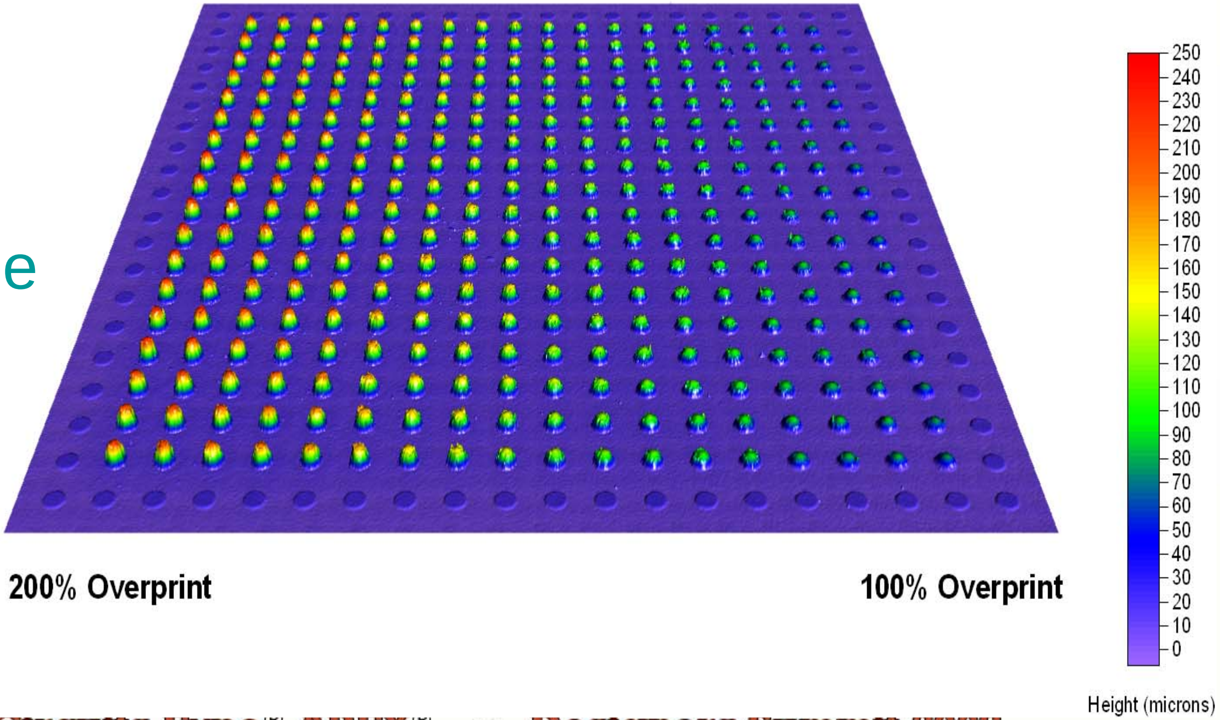


Substrate Bumping

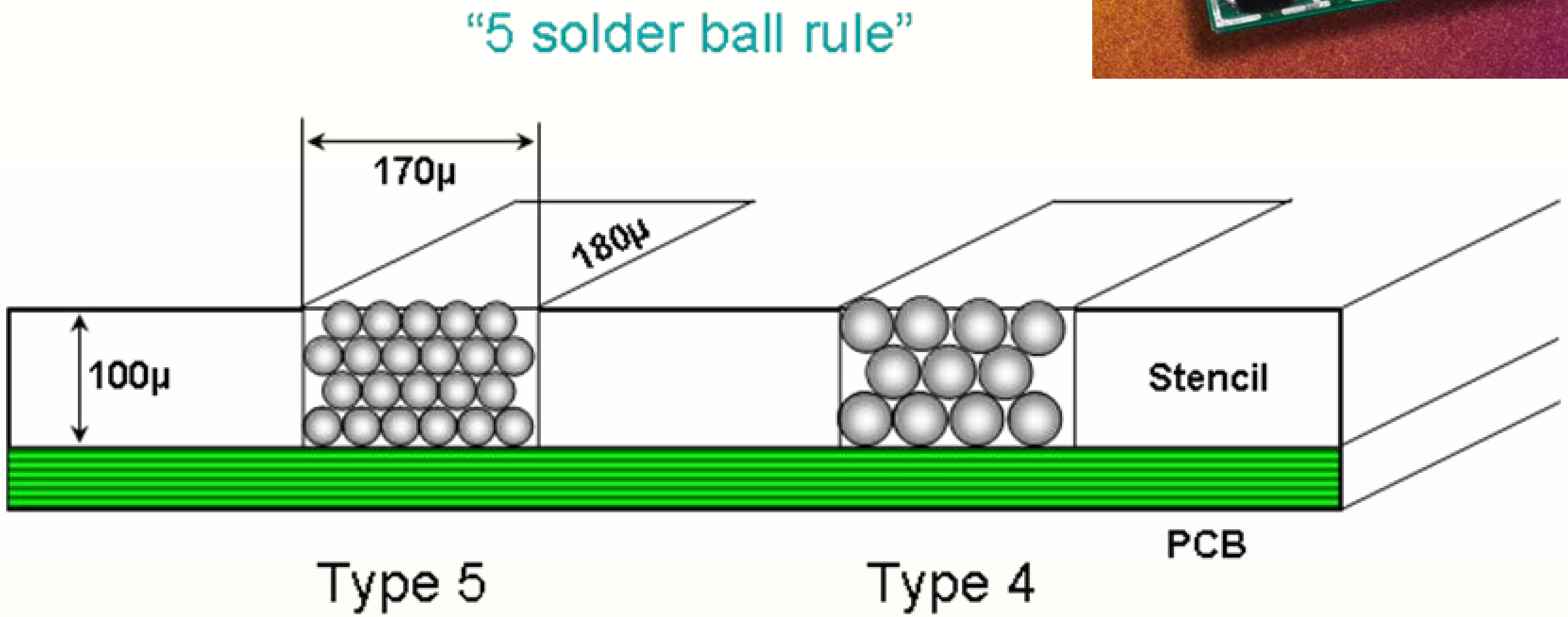


- Typically aperture size = UBM size
- Powder type 5,6 & 7 common
- Water clean formulations

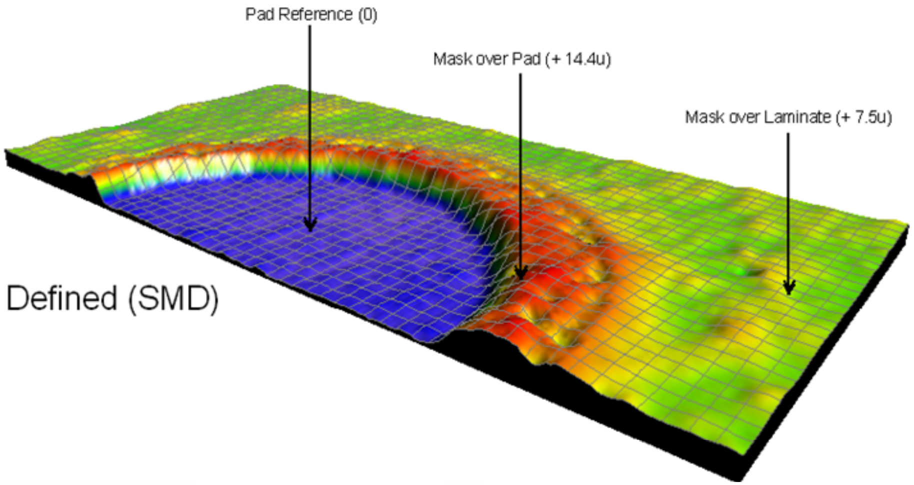
50µ Stencil example



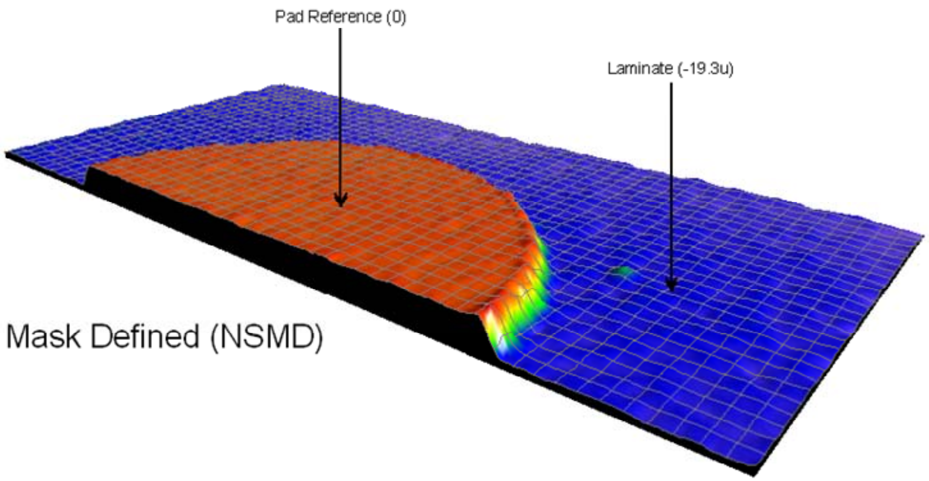
System in Package (01005)



Solder On Pad (thin stencils)



Solder Mask Defined (SMD)



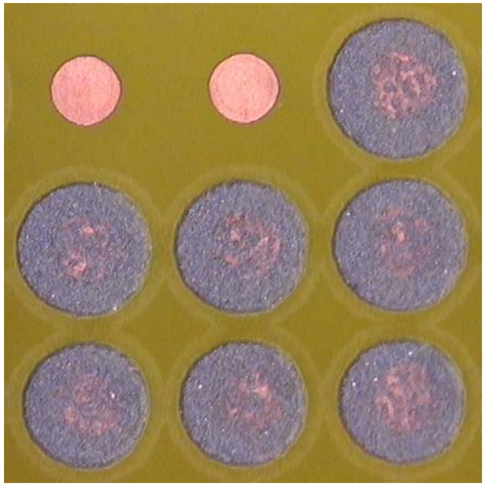
Non Solder Mask Defined (NSMD)

SoP = Thin Solder = Thin Stencils = Fine Powders

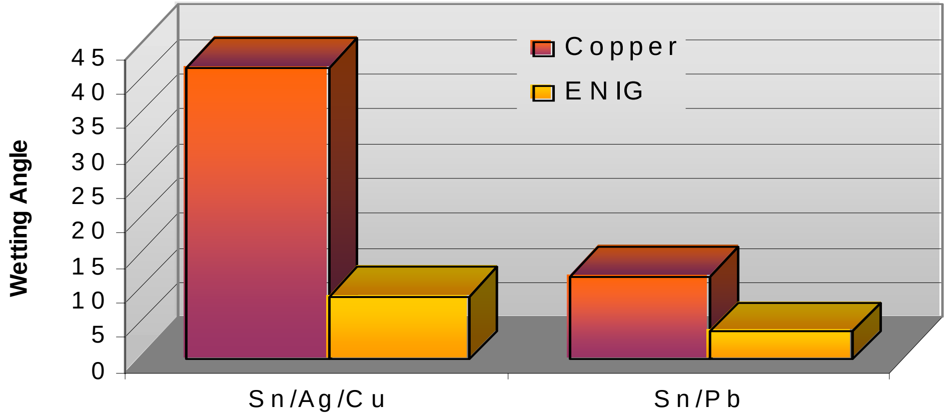
25µ Stencil

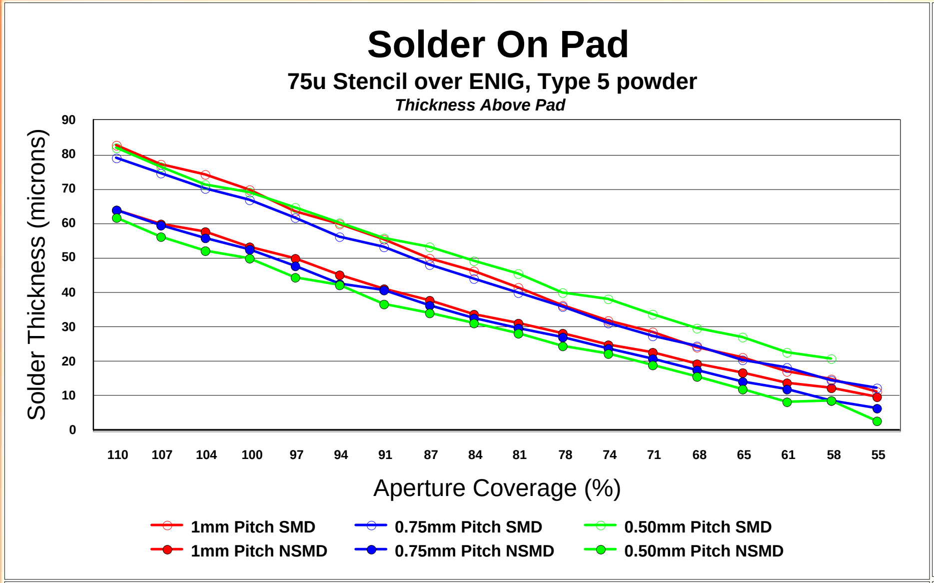
Type 5 Powder

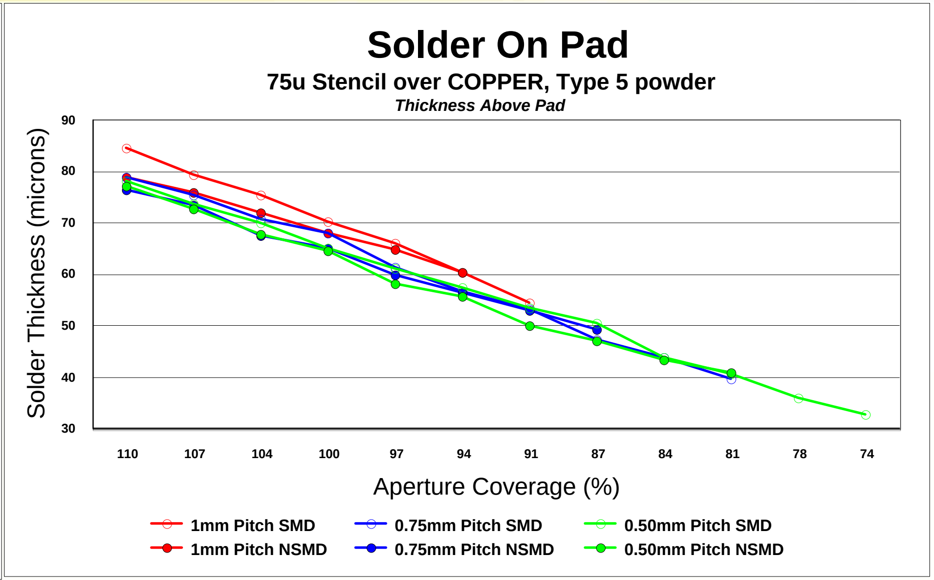
(10µ – 25µ)

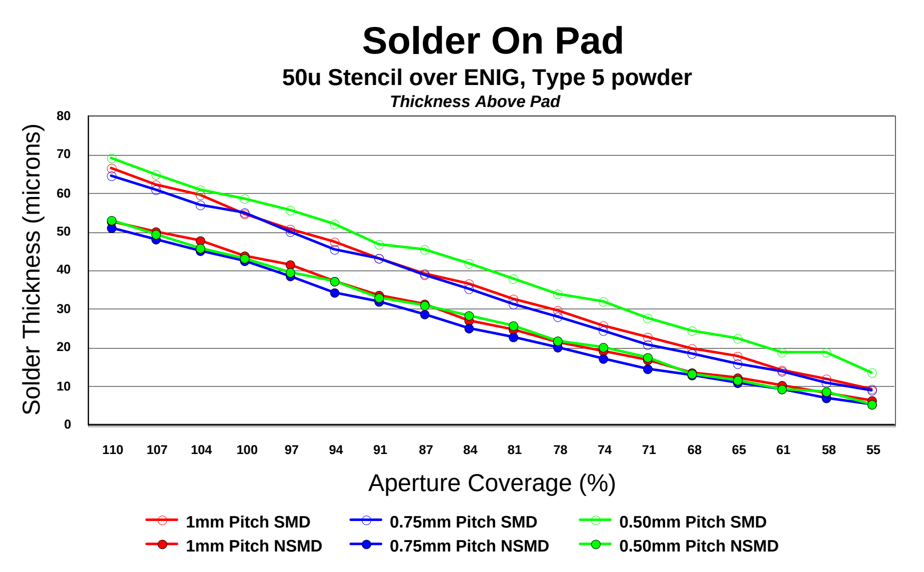


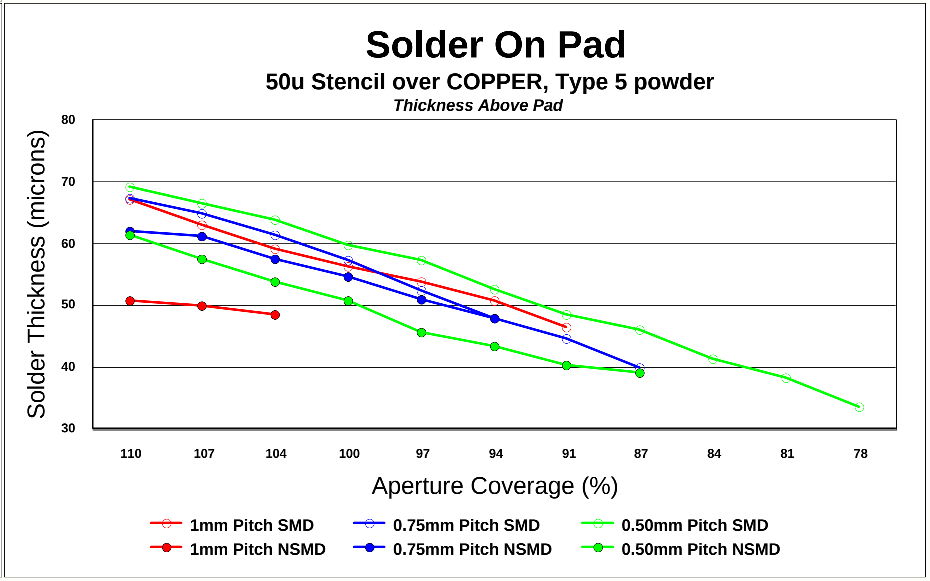
SoP = 100% Solder Coverage = Wettability



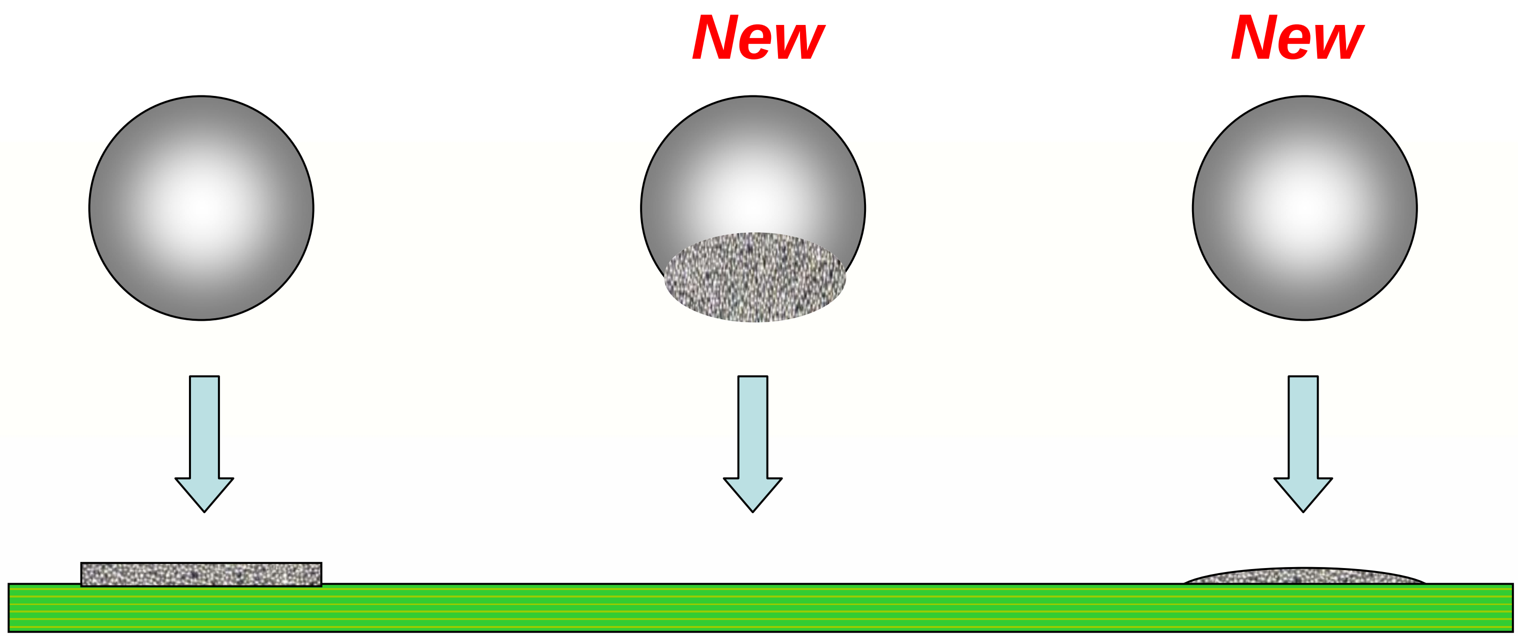

Solder On Pad
75u Stencil over ENIG, Type 5 powder
Thickness Above Pad
Solder Thickness (microns)
90
80
70
60
50
40
30
20
10
0
110
107
104
100
97
94
91
87
84
81
78
74
71
68
65
61
58
55
Aperture Coverage (%)
1mm Pitch SMD
0.75mm Pitch SMD
0.50mm Pitch SMD
1mm Pitch NSMD
0.75mm Pitch NSMD
0.50mm Pitch NSMD


Solder On Pad
75u Stencil over COPPER, Type 5 powder
Thickness Above Pad
Solder Thickness (microns)
90
80
70
60
50
40
30
110
107
104
100
97
94
91
87
84
81
78
74
Aperture Coverage (%)
1mm Pitch SMD
0.75mm Pitch SMD
0.50mm Pitch SMD
1mm Pitch NSMD
0.75mm Pitch NSMD
0.50mm Pitch NSMD


Solder On Pad
50u Stencil over ENIG, Type 5 powder
Thickness Above Pad
Solder Thickness (microns)
80
70
60
50
40
30
20
10
0
110
107
104
100
97
94
91
87
84
81
78
74
71
68
65
61
58
55
Aperture Coverage (%)
1mm Pitch SMD
0.75mm Pitch SMD
0.50mm Pitch SMD
1mm Pitch NSMD
0.75mm Pitch NSMD
0.50mm Pitch NSMD


Solder On Pad
50u Stencil over COPPER, Type 5 powder
Thickness Above Pad
Solder Thickness (microns)
80
70
60
50
40
30
110
107
104
100
97
94
91
87
84
81
78
Aperture Coverage (%)
1mm Pitch SMD
0.75mm Pitch SMD
0.50mm Pitch SMD
1mm Pitch NSMD
0.75mm Pitch NSMD
0.50mm Pitch NSMD

BGA ball attach methods



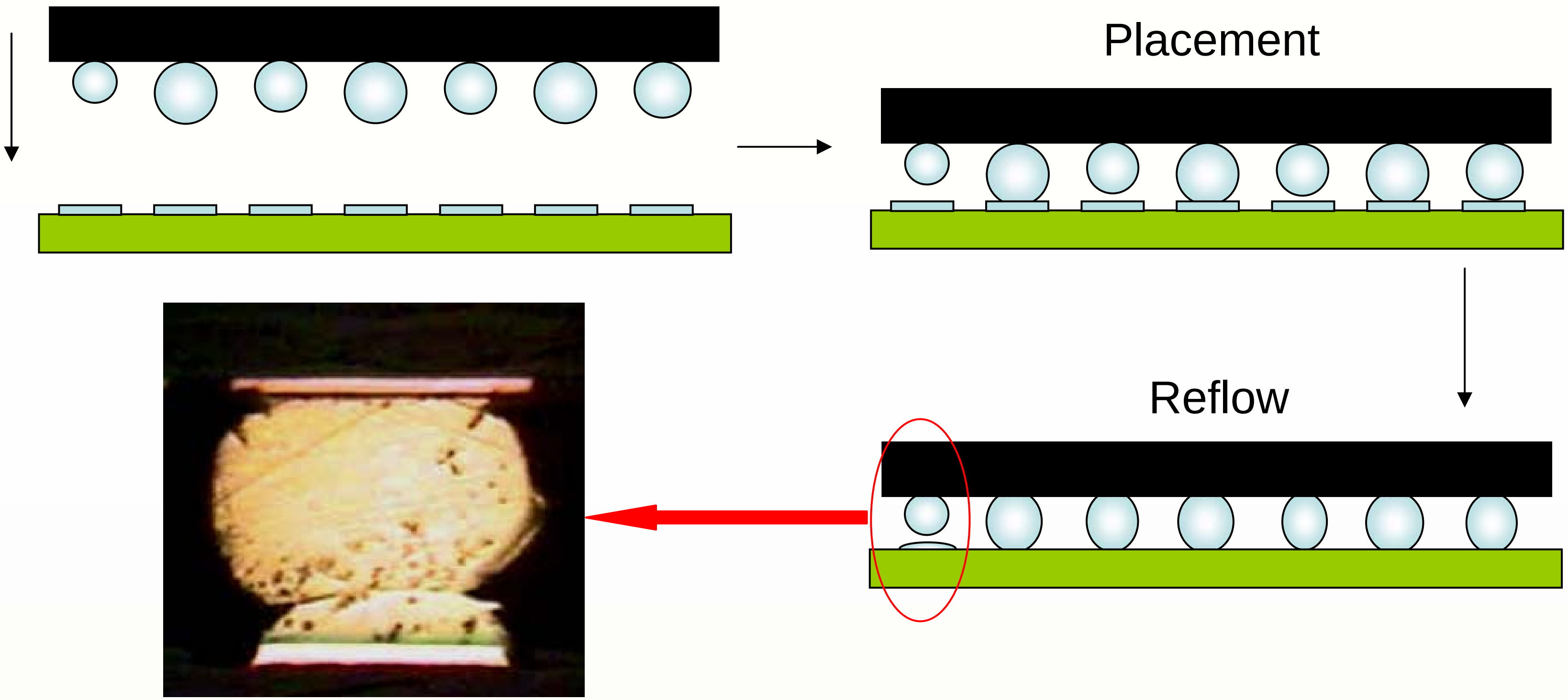
Ball drop onto printed paste

Ball dip into dippable paste then dropped

Ball drop onto pin transferable paste

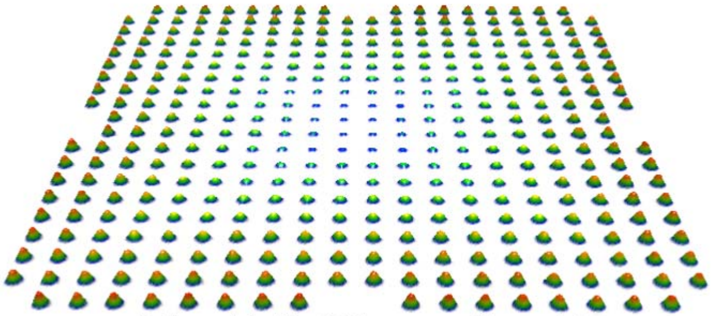
Printed Paste - Opportunity for Coplanarity Reduction

- Ball in Cup (BIC) aka “Ball in Socket” defects
  - Difficult to verify at test or X-ray
  - Intermittent opens

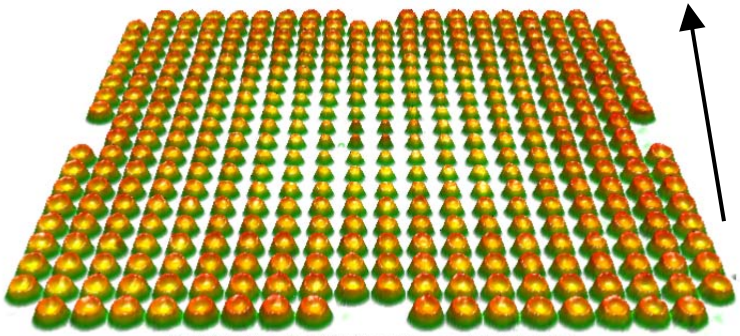


BIC photo courtesy of Delphi

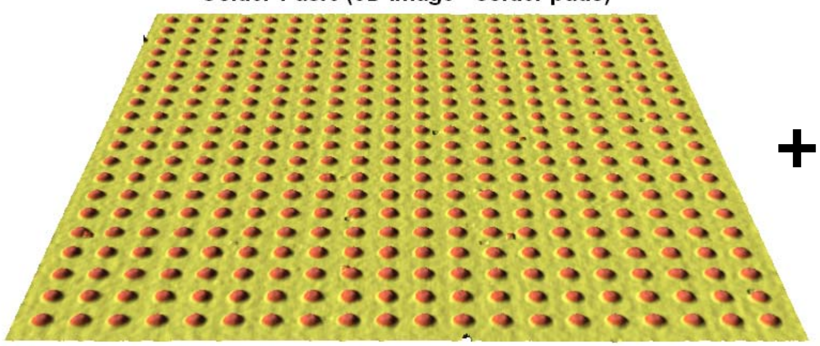
BGA Coplanarity Reduction Basic Concept



Reflowed Solder (3D image - solder pads)

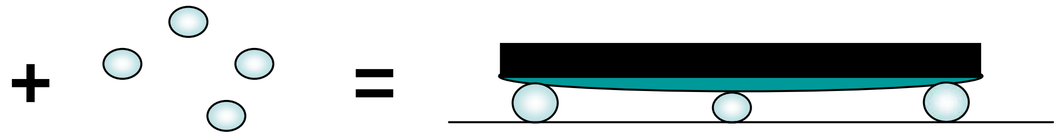


Solder Paste (3D image - solder pads)

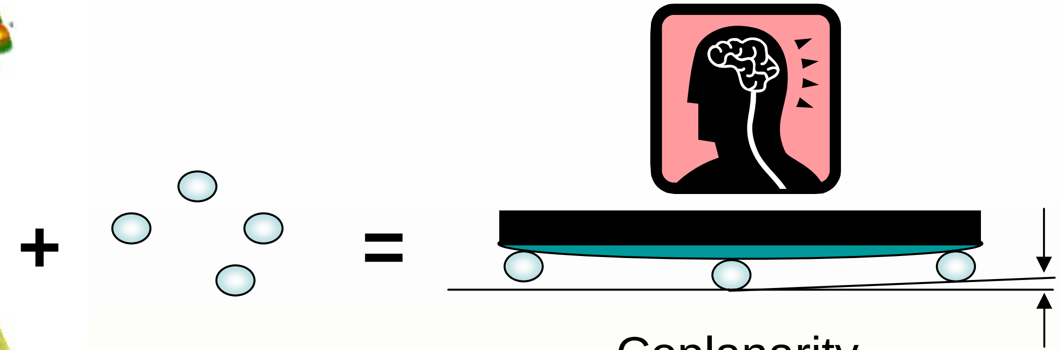


Solder Pads (3D image)

Variable Solder Volume



Reduced Coplanarity



Coplanarity

Experimental Work to Quantify Impact of Concept

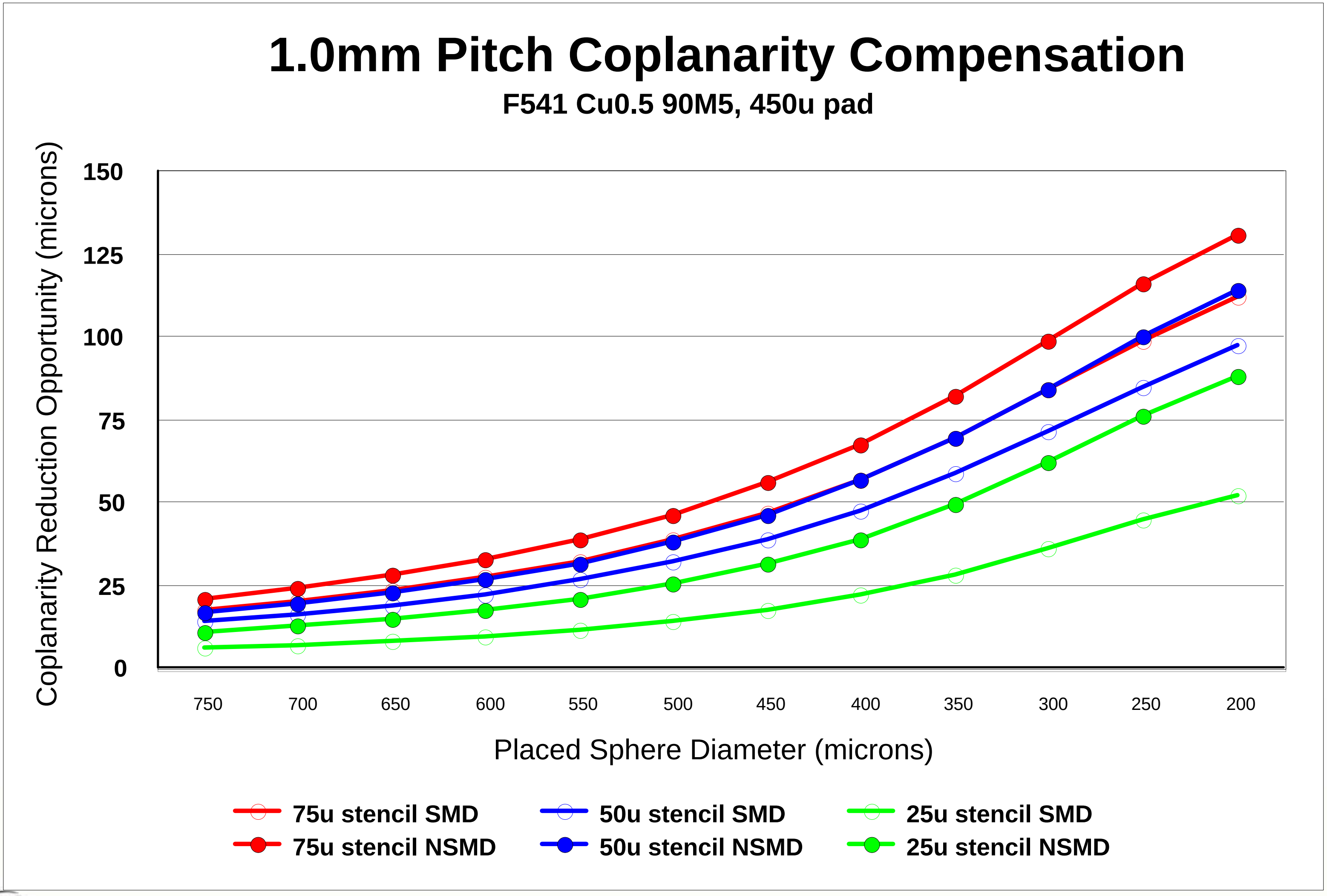
- Four Pitches
  - 1.27mm, 1mm, 0.75mm & 0.5mm
- Two Pad Constructs
  - Solder Mask Defined, Non Solder Mask Defined
- Three Stencil Thickness's
  - 25µ, 50µ & 75µ
- One paste F541Cu0.5 90M5
  - Water Wash, SAC405, 90% metal, Medium viscosity, Type 5 powder
- One Board Finish
  - OSP
- Aperture Designs – Round
  - 100% -200% pad coverage in 18 steps

Coplanarity Reduction Estimation

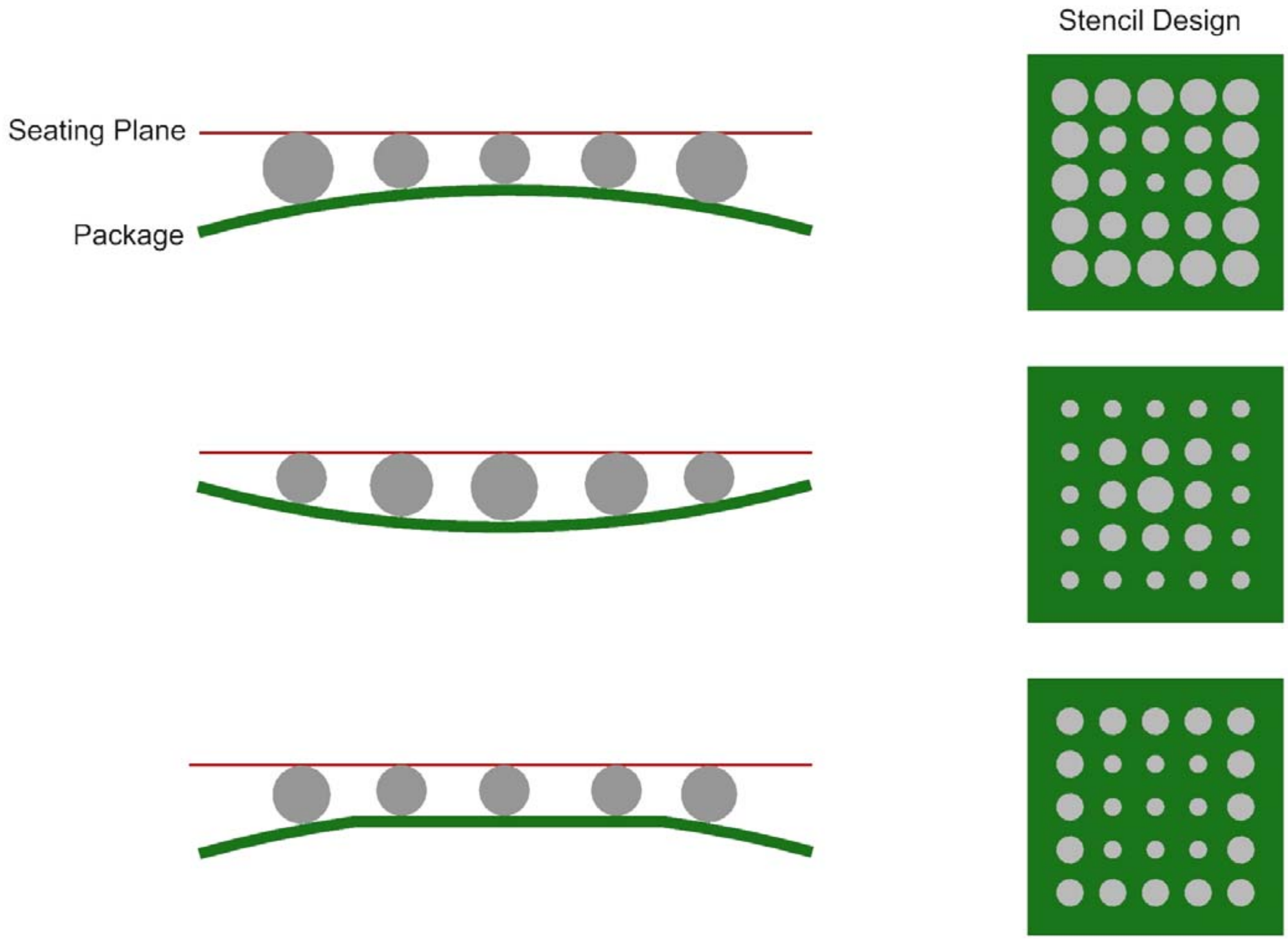
- **Volume of a sphere:** $v = \frac{4}{3} \pi r^3$
- **Attached Sphere Volume:** $v_{sphere} + v_{paste(reflowed)}$
- **Volume of a Compressed Truncated Sphere*:** $V_{CTS} = \frac{\pi}{24}\left(3h\phi_{pad}^2 + 4ah^3\right)$
- **Coplanarity compensation opportunity is simply the reflowed attached sphere height difference between the largest and smallest sphere due to varying the solder paste volume.**

** Formula courtesy of Dr Scott Popelar, IC Interconnect*

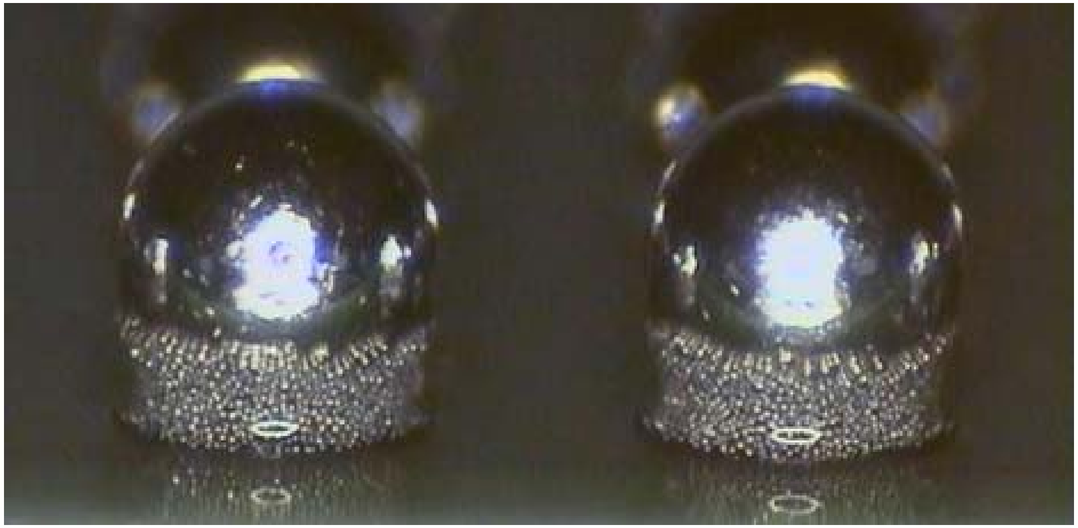
Coplanarity Reduction Projections



Implementation Schemes



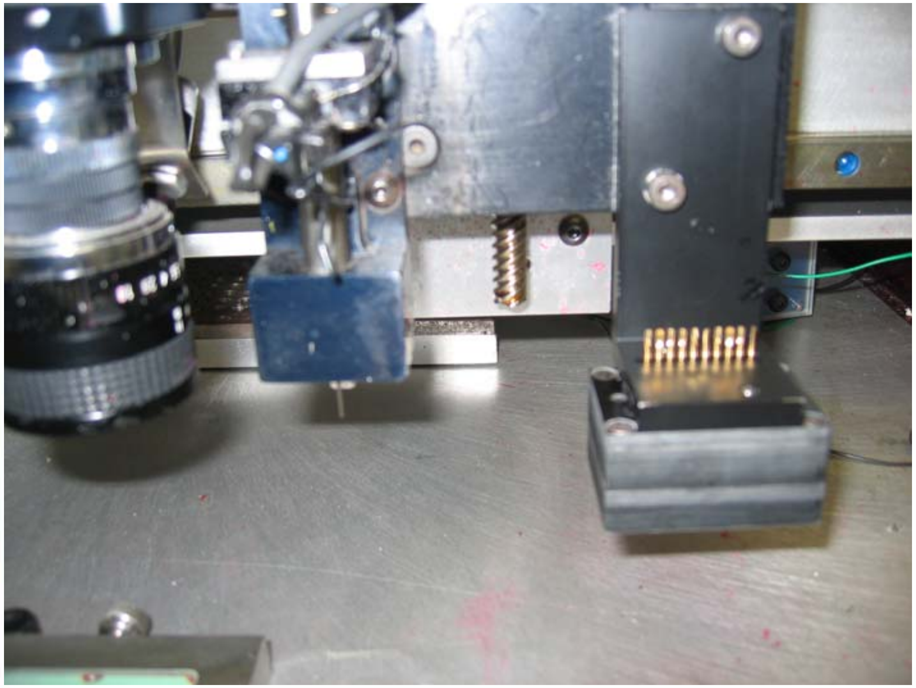
SoP is Importunity for Dippable Pastes (ball shorts)



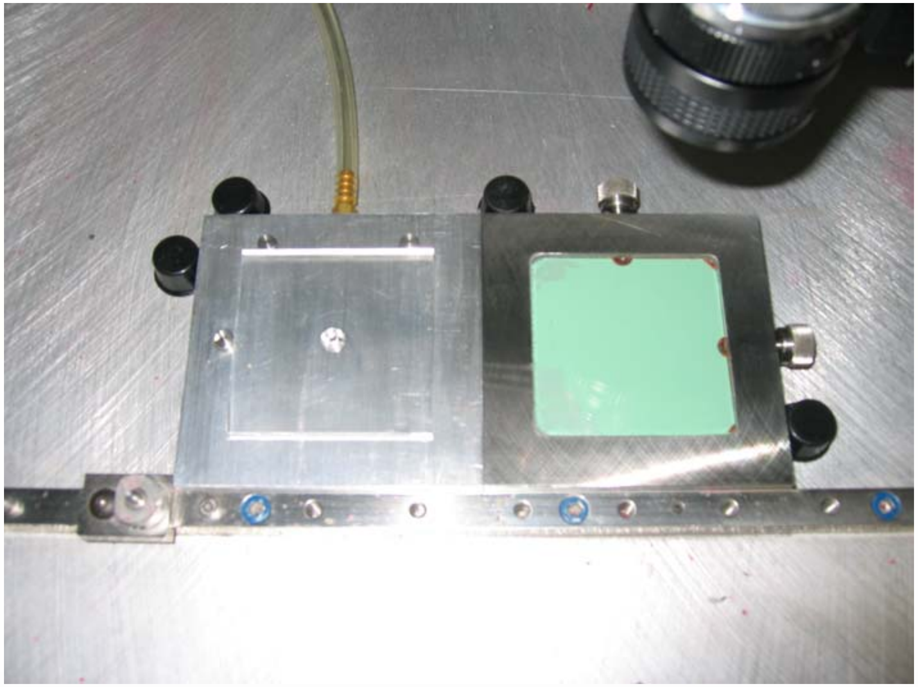
Ball Dip
(*Courtesy of TI*)

Pin Transfer
(*Courtesy of Amkor*)

Pin Transferability Testing



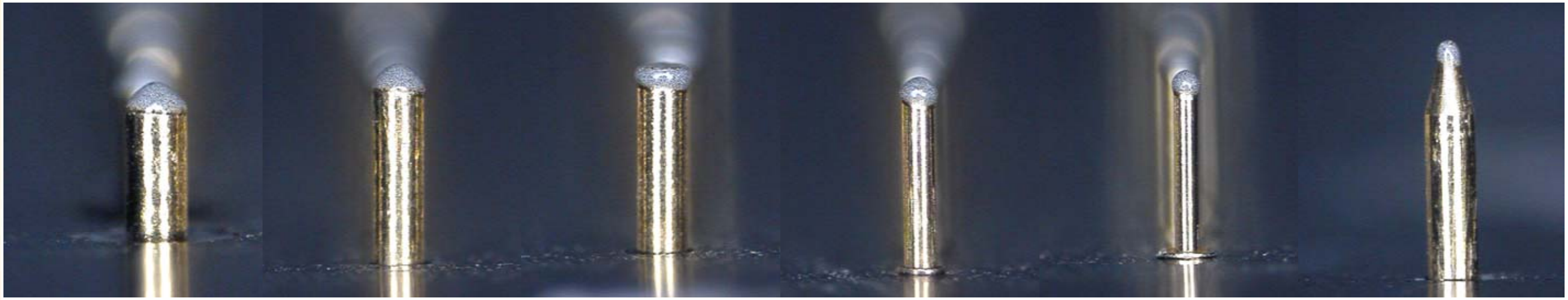
Multi-sized Pin Block



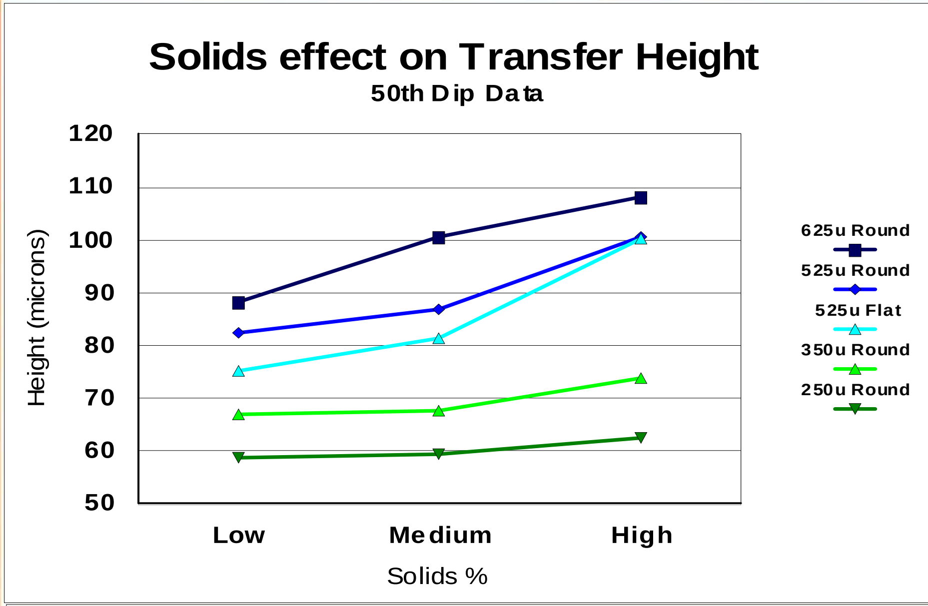
Dip well and Glass Substrate

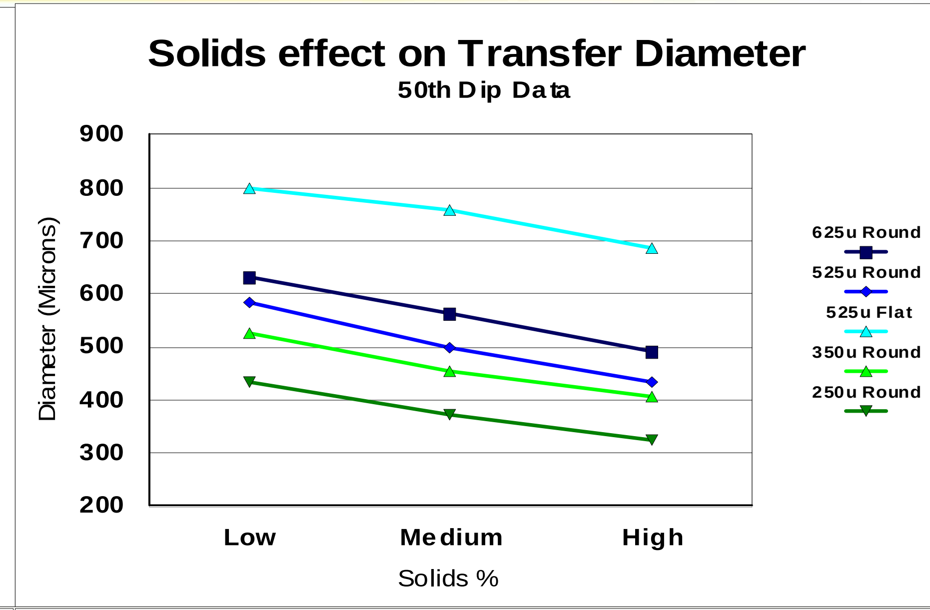
Pin Sizes and Wetting

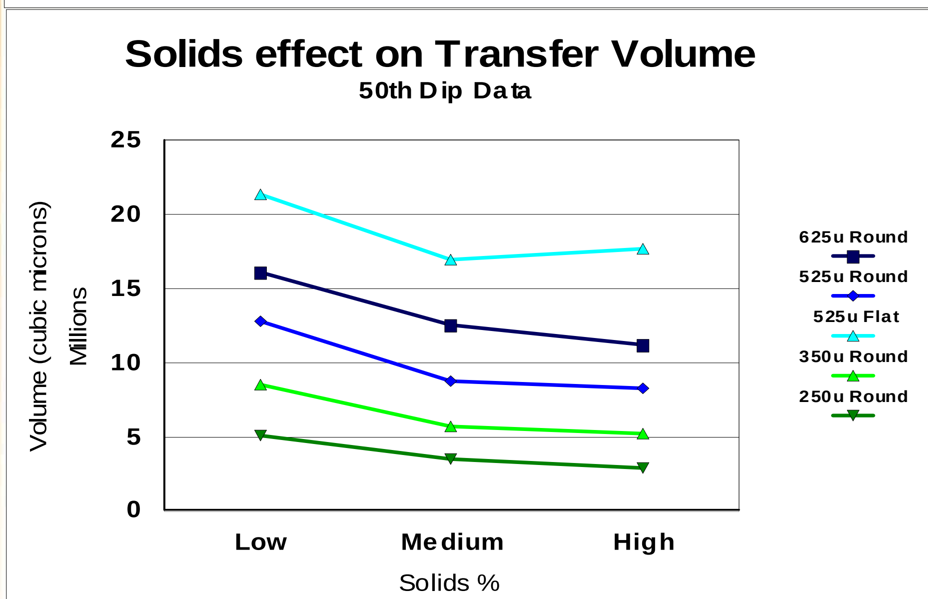
Type 5 Powder- BD41 Series

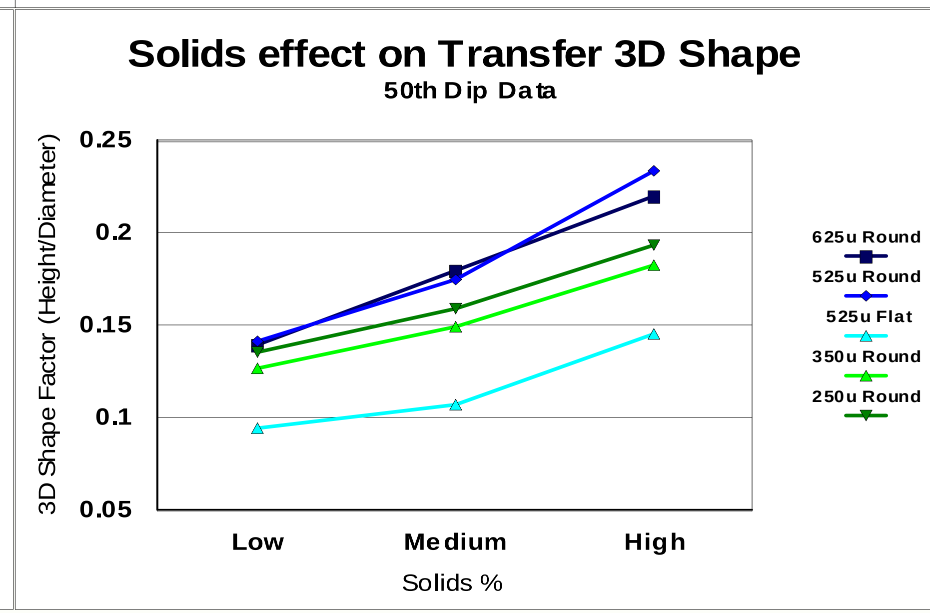


625u Round	525u Round	525u Flat	350u Round	250u Round	Point (fiducial)


Solids effect on Transfer Height
50th Dip Data
Height (microns)
120
110
100
90
80
70
60
50
Low
Medium
High
Solids %
625u Round
525u Round
525u Flat
350u Round
250u Round

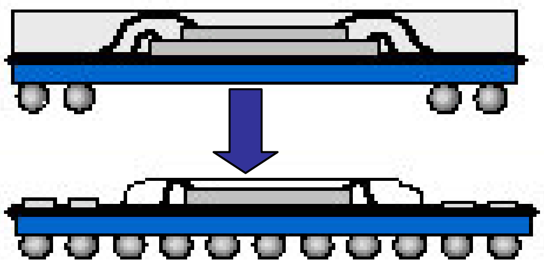

Solids effect on Transfer Diameter
50th Dip Data
Diameter (Microns)
900
800
700
600
500
400
300
200
Low
Medium
High
Solids %
625u Round
525u Round
525u Flat
350u Round
250u Round


Solids effect on Transfer Volume
50th Dip Data
Volume (cubic microns)
Millions
25
20
15
10
5
0
Low
Medium
High
Solids %
625u Round
525u Round
525u Flat
350u Round
250u Round

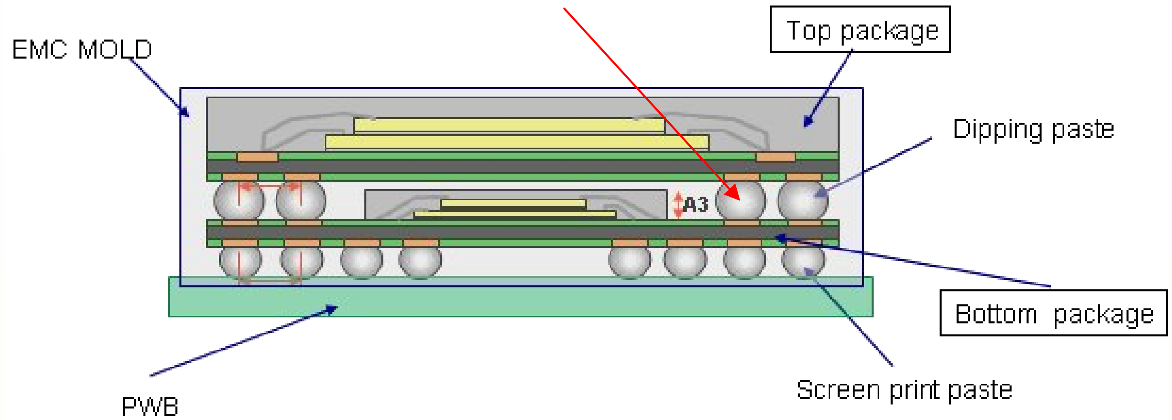

Solids effect on Transfer 3D Shape
50th Dip Data
3D Shape Factor (Height/Diameter)
0.25
0.2
0.15
0.1
0.05
Low
Medium
High
Solids %
625u Round
525u Round
525u Flat
350u Round
250u Round

Package on Package Opportunities

- **Coplanarity**
  - Top BGA
  - Thermal warpage



- **Increase Standoff**
  - Increase upper module ball diameter during reflow



Questions?

Heraeus