TI OMAP4xxx POP SMT Design Guideline

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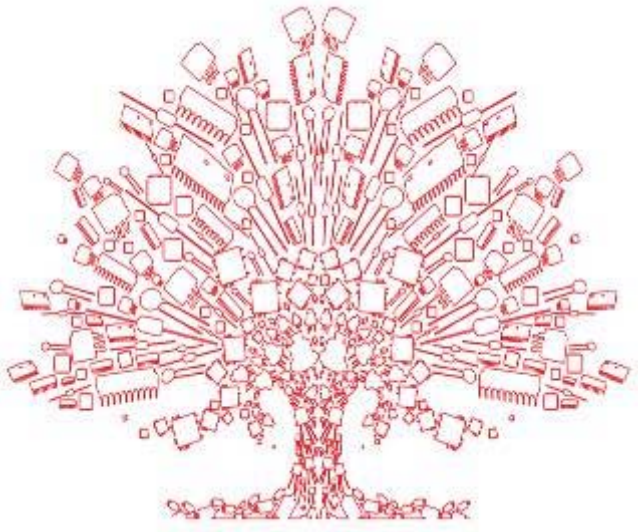

We Support One Make

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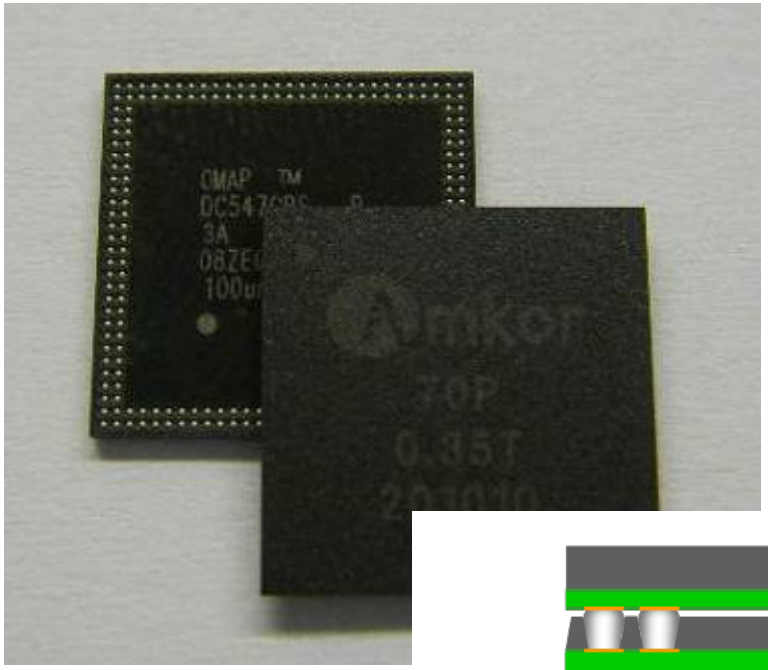
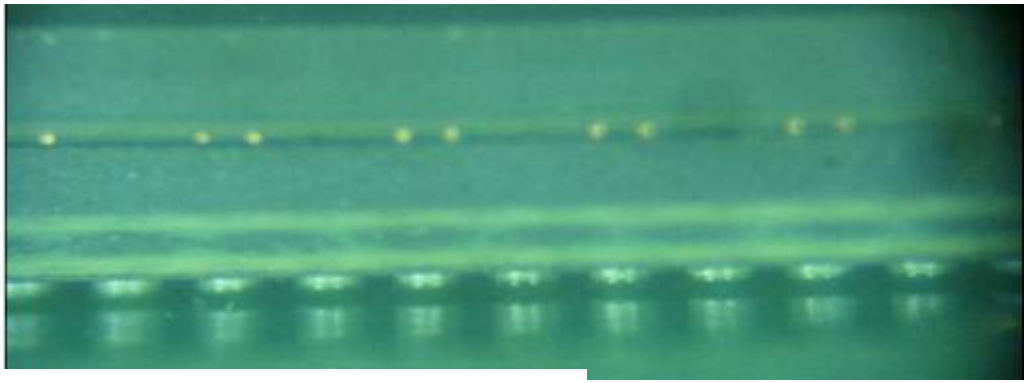
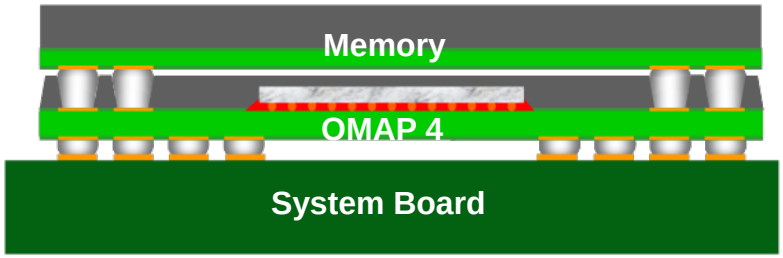
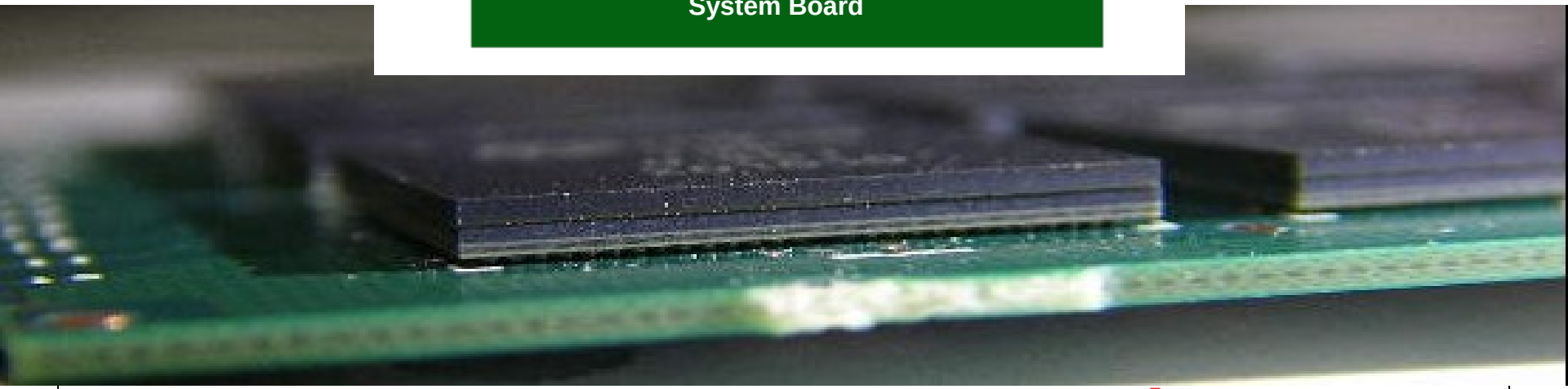
OMAP4XXX POP Packages



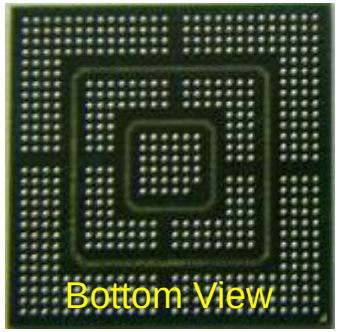


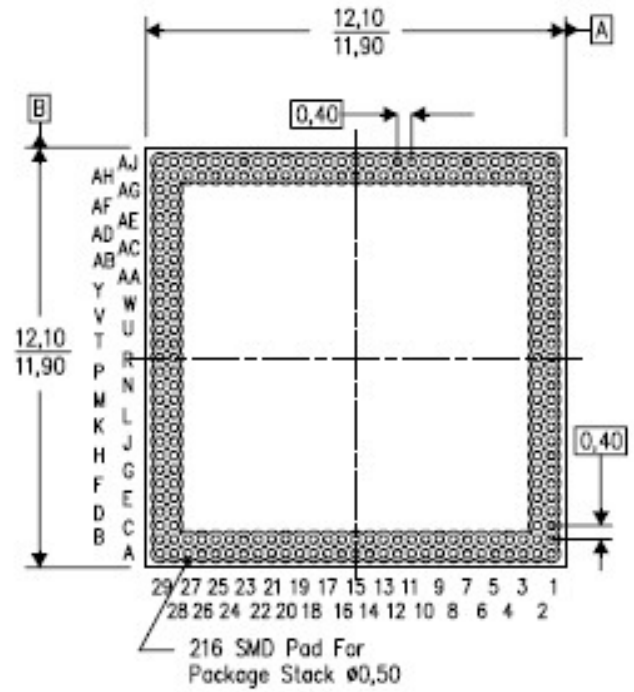


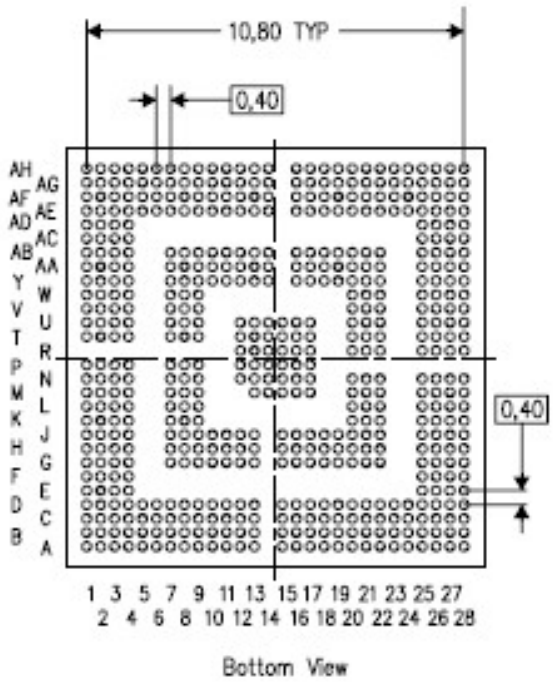


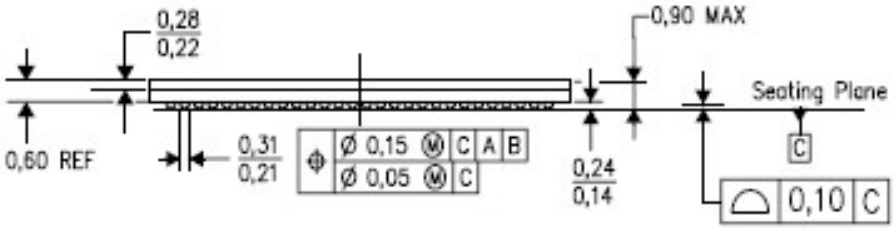
Mechanical Drawing of OMAP4xxx CBS (TMV)

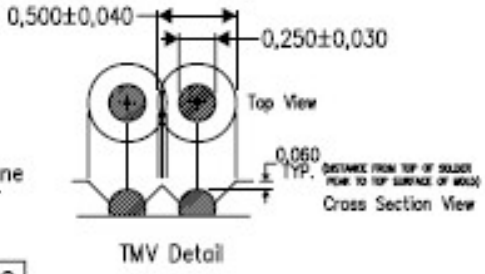
OMAP4xxx



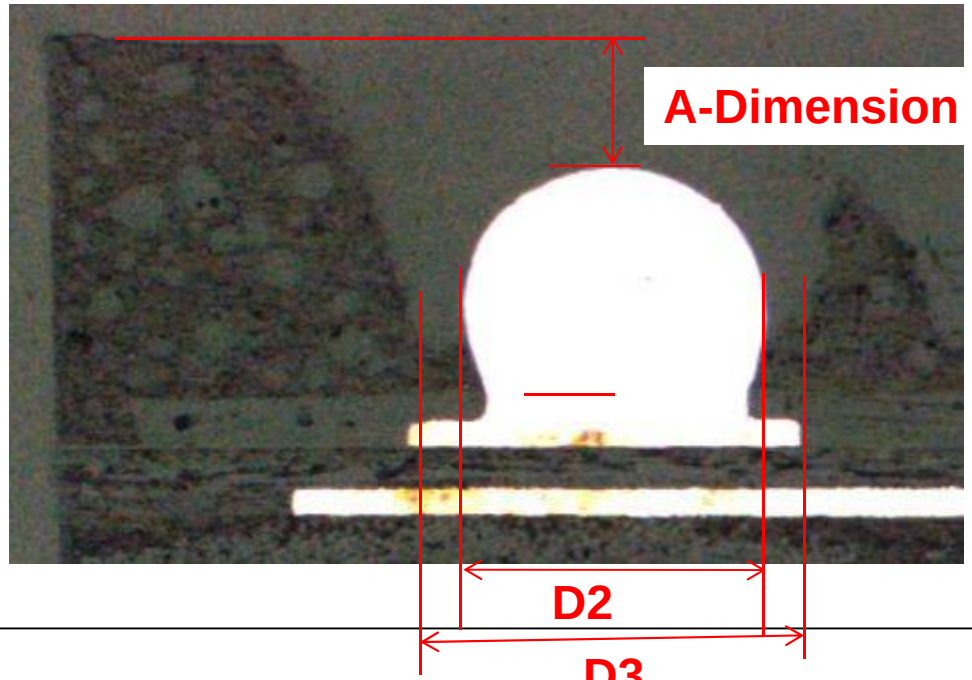


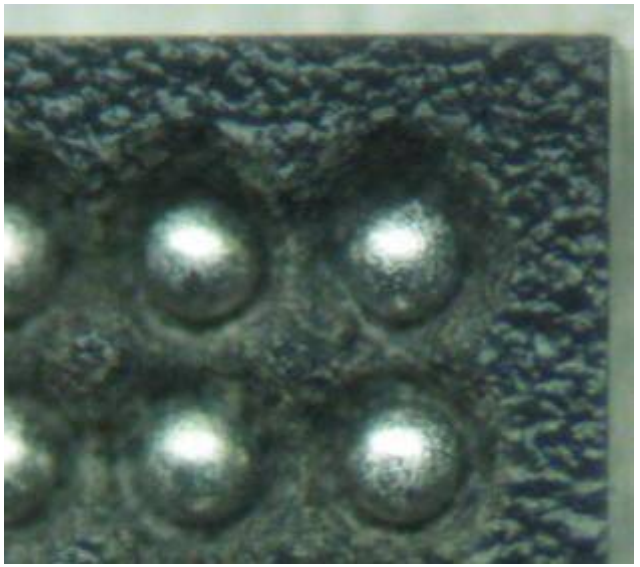




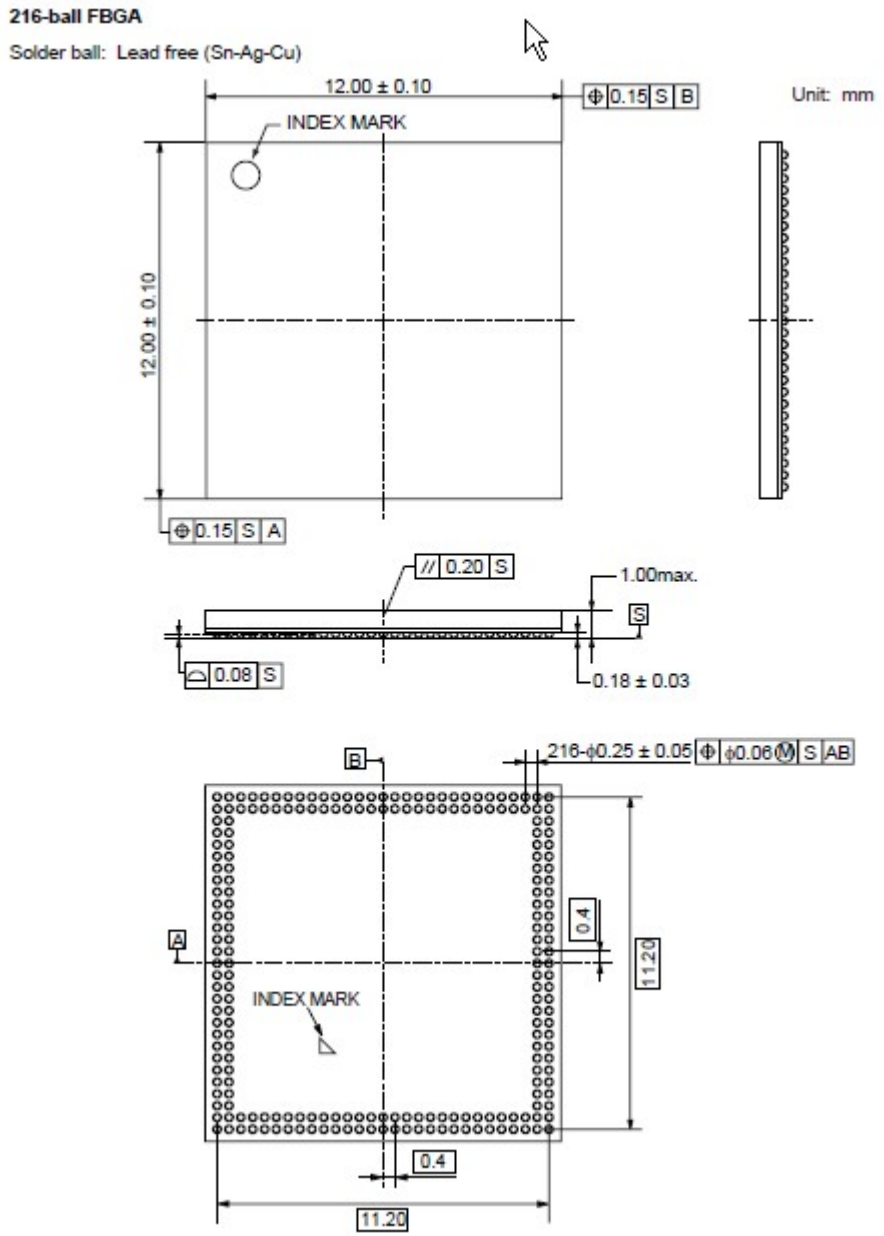


OMAP4xxx TMV

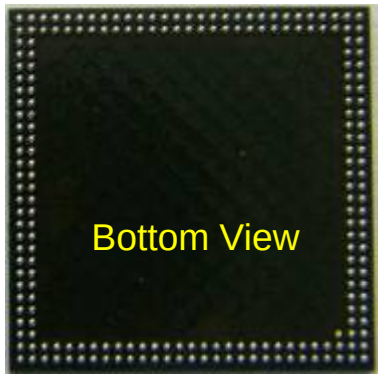




Mechanical Drawing of Memory Chip



Memory Chip



Agenda:

- Package Introduction
- OMAP4 SMT Process sharing
  - ✓Stencil/PCB design guide
  - ✓Memory chip flux/solder dipping in 1-step mounting
  - ✓The example of Pick & Place machine condition setting
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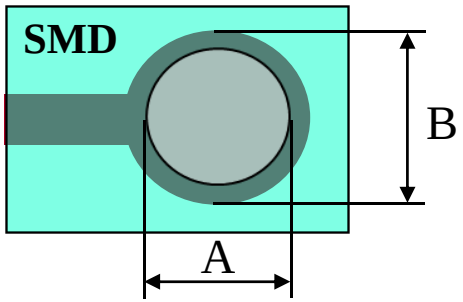
  - ✓SMT experiment examples
- Q& A

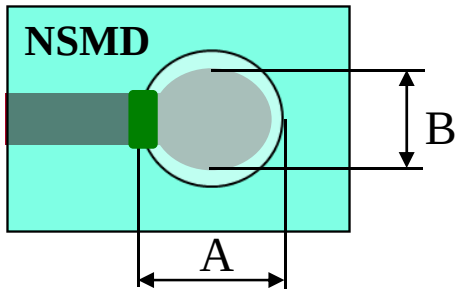
Stencil/PCB design guide for P0.4 OMAP4

PWB Land & Stencil aperture design Recommendation for pitch 0.4mm

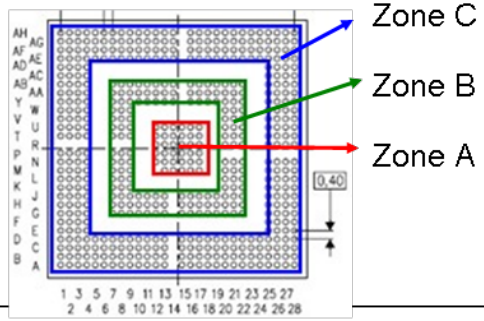
Solder Mask Defined



Non Solder Mask Defined



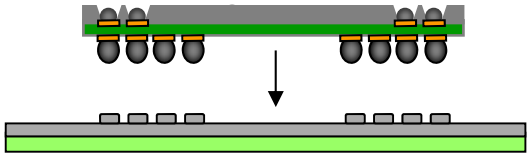
Ball Pitch		PWB Design A	PWB Design B	Stencil Design Thickness	Stencil Design Opening	
0.4mm	SMD*	0.23	0.28	0.08/0.1	0.25	(Zone C)
				0.08/0.1	0.20	(Zone A+B)
	NSMD	0.28	0.23	0.08/0.1	0.25	(Zone C)
				0.08/0.1	0.20	(Zone A+B)



- Avoid VIP(Via in Pad) design. If should do it, the plugged via with flatten surface is recommended.
- SMD design is more suggested than NSMD to prevent the solder starvation form trace neck or irregular joint shape.
- Trace design: No big ground with several pads connection or wide trace neck.
- Square opening of Stencil can get more volume for joint print.

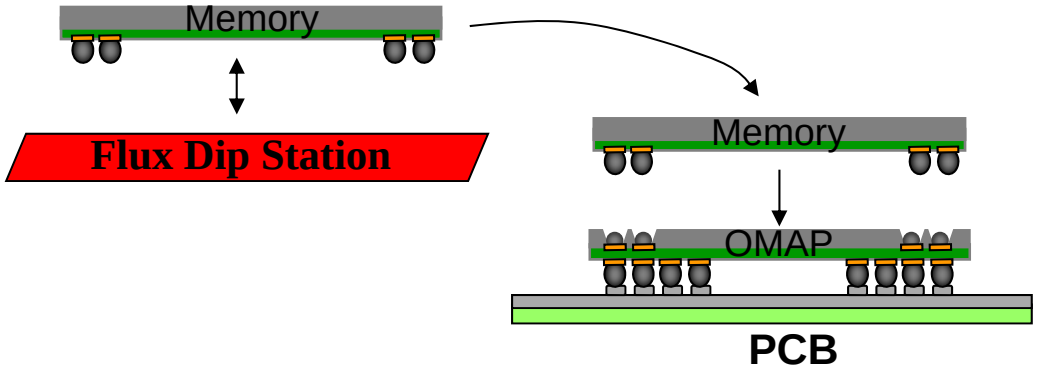
Package on Package (POP)
Surface Mount Assembly Process Flow

- Screen print solder paste to PCB
- Pick and place OMAP BGA



PCB

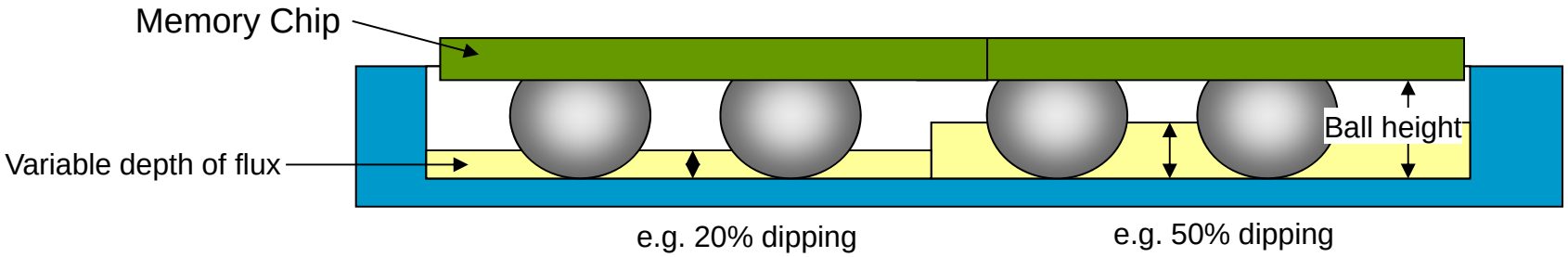
- Dip Memory package into flux or paste
- Place on top of OMAP package

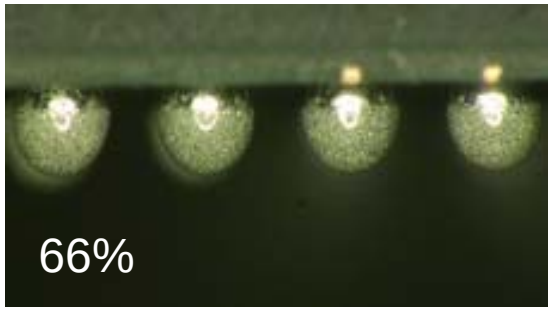


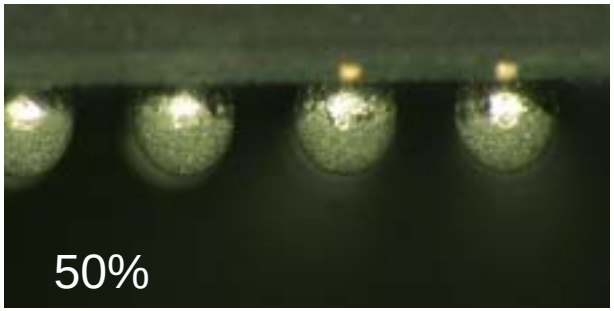
- Reflow to form POP stack

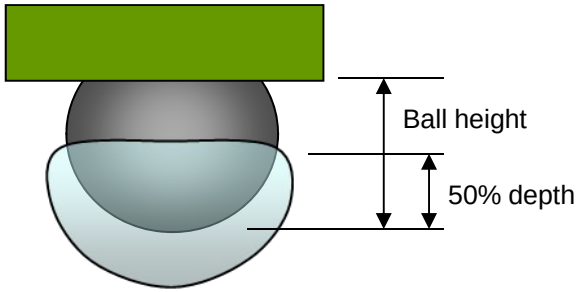
Memory chip flux/solder dipping recommendation in 1-step mounting

"A" memory DC package, is dipped into flux with variable depth







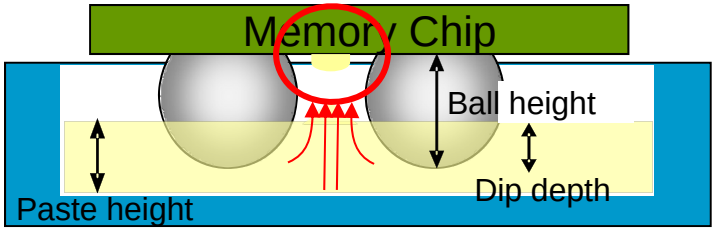


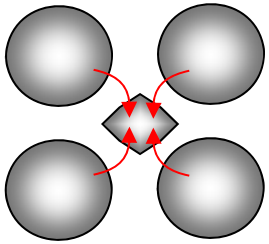
50% is appropriate dipping depth

Flux/solder past dip depth:

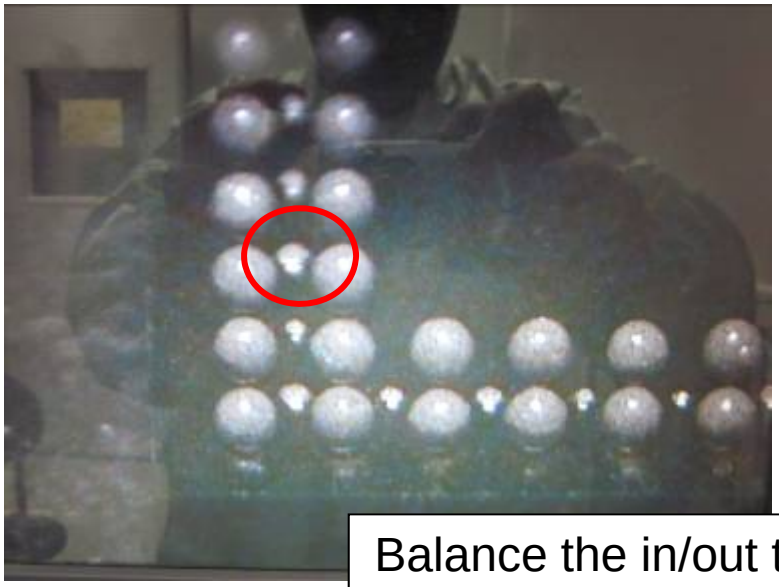
From the evaluation, the optimal results at 50-70 % flux dip and solder paste.

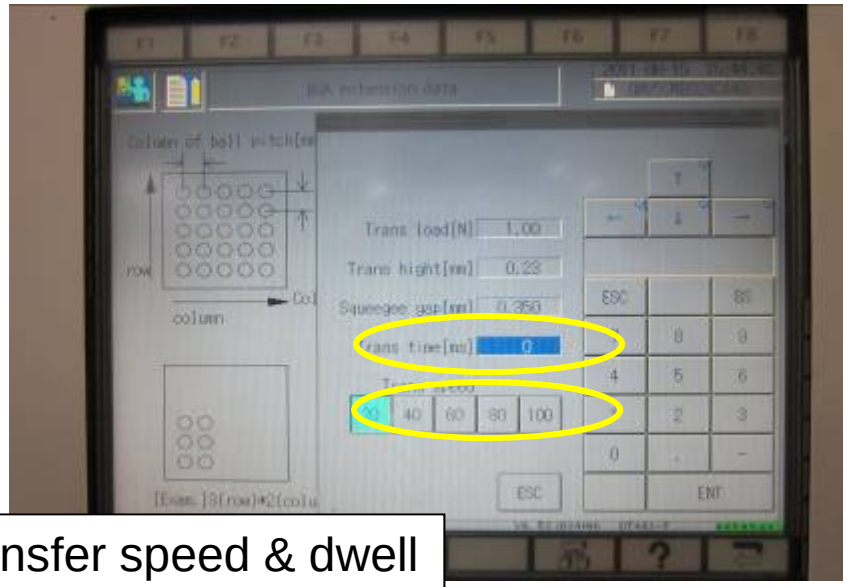
Memory Paste dipping & SMT Machine Control Setting





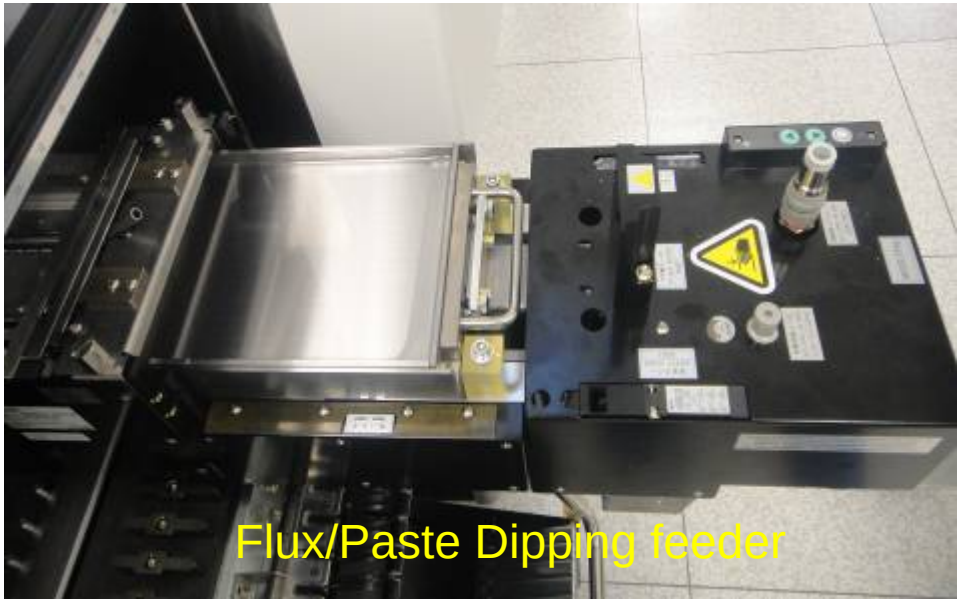
Memory Dip too fast + paste suppress by 4 balls and extrude the additional paste up & attached on the bottom of substrate surface.



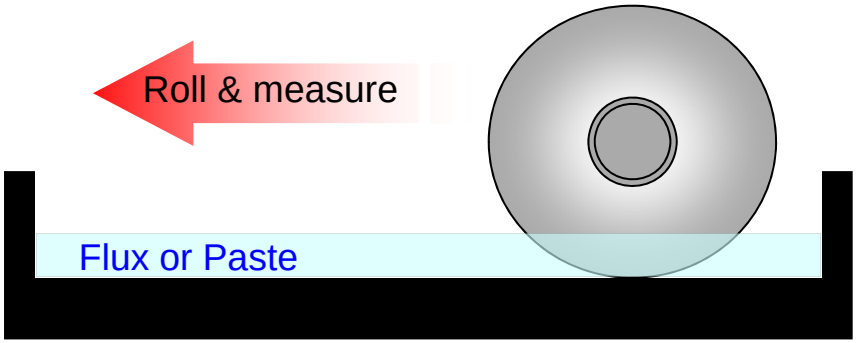


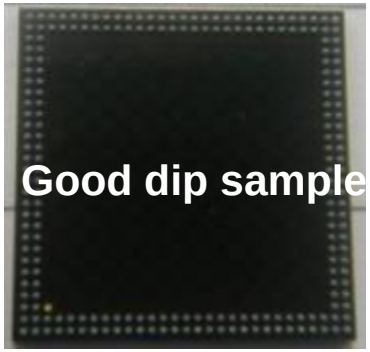
Balance the in/out transfer speed & dwell time to get optimized solder dipping.

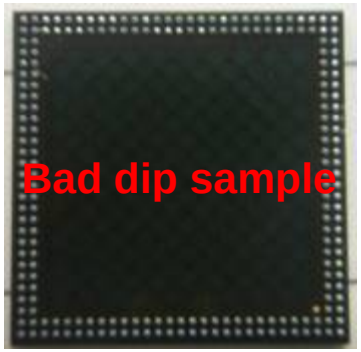
Flux/Solder Paste Depth Measurement



Flux/paste dipping depth was measured by using height gauge shown in below picture.







The dipping performance contributed the top level soldering yield directly.

Measurement of flux depth (Example)

ERICHSEN
TESTING EQUIPMENT

Wet Film Thickness Gauge 433

ISO, BS

One instrument only for 4 measuring ranges: 5 - 100 microns, 100 - 500 microns, 300 - 700 microns, 700 - 1500 microns. This comb-shaped instrument, made of stainless steel, stands out for high accuracy.

Wet Film Thickness Gauge 234

DIN, ASTM, BS, ISO, NF

A hardened and ground double wheel with an eccentric cam in the middle is rolled over a newly applied film. The wetting line on the middle cam is read off on a scale as wet film thickness. Total measuring range: 1500 microns, available in 8 different sub-ranges.

Condition of PnP M/C setting (example)

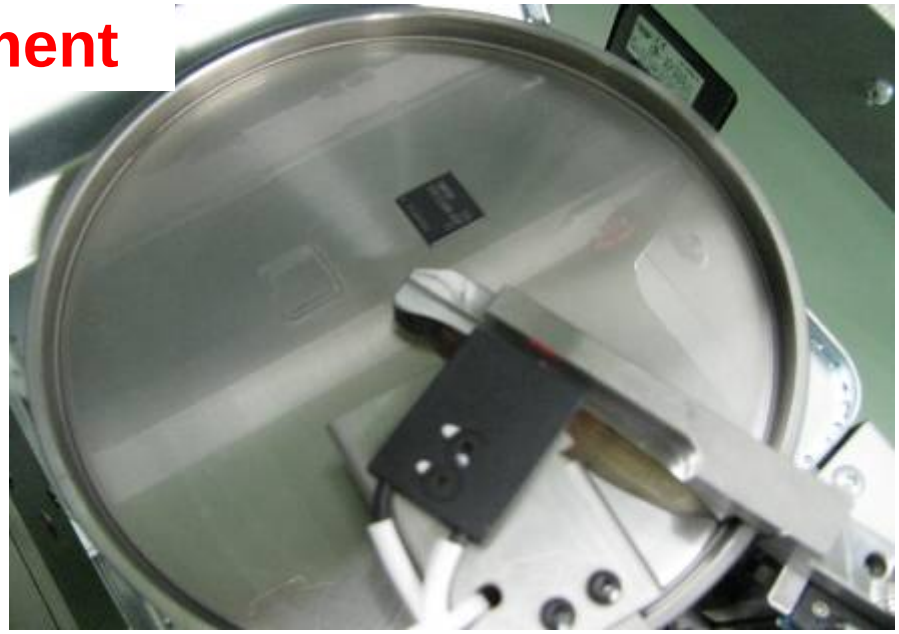
Placement Parameters:

- ✓SMT M/C Brand: Panasonic
- ✓Type: NPM
- ✓Device Placement: OMAP4 + Memory Chip
- ✓Placement method: By 1-step
- ✓Fiducial marks recognition for placement:
  By Board fiducial
- ✓Pick up Nozzle type: 1004
- ✓Nozzle size: ~8mm (with robber tip)
- ✓Memory Vision sequence: Pickup + Camera vision + Memory Dipping + Placement
- ✓Dwell time of memory dipping: 400ms ~1 sec
- ✓Placement Force (N) or placement depth (um):
  - For OMAP4: package height+1~2.5N (push down)
  - For Memory Chip: package height+1~2.5N (push down)

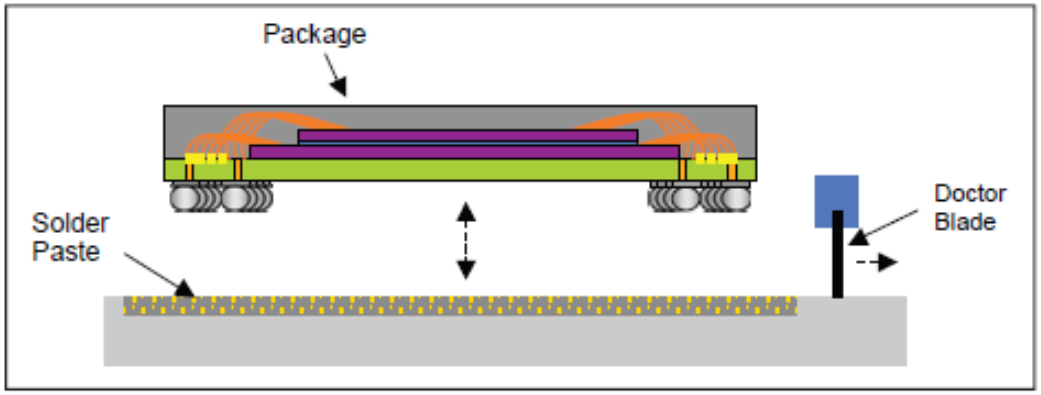
Nozzle type: 1004

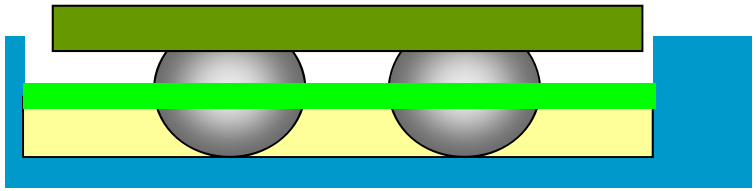
Bottom and Top BGA Placement

Surface Mounter: Fuji NXT



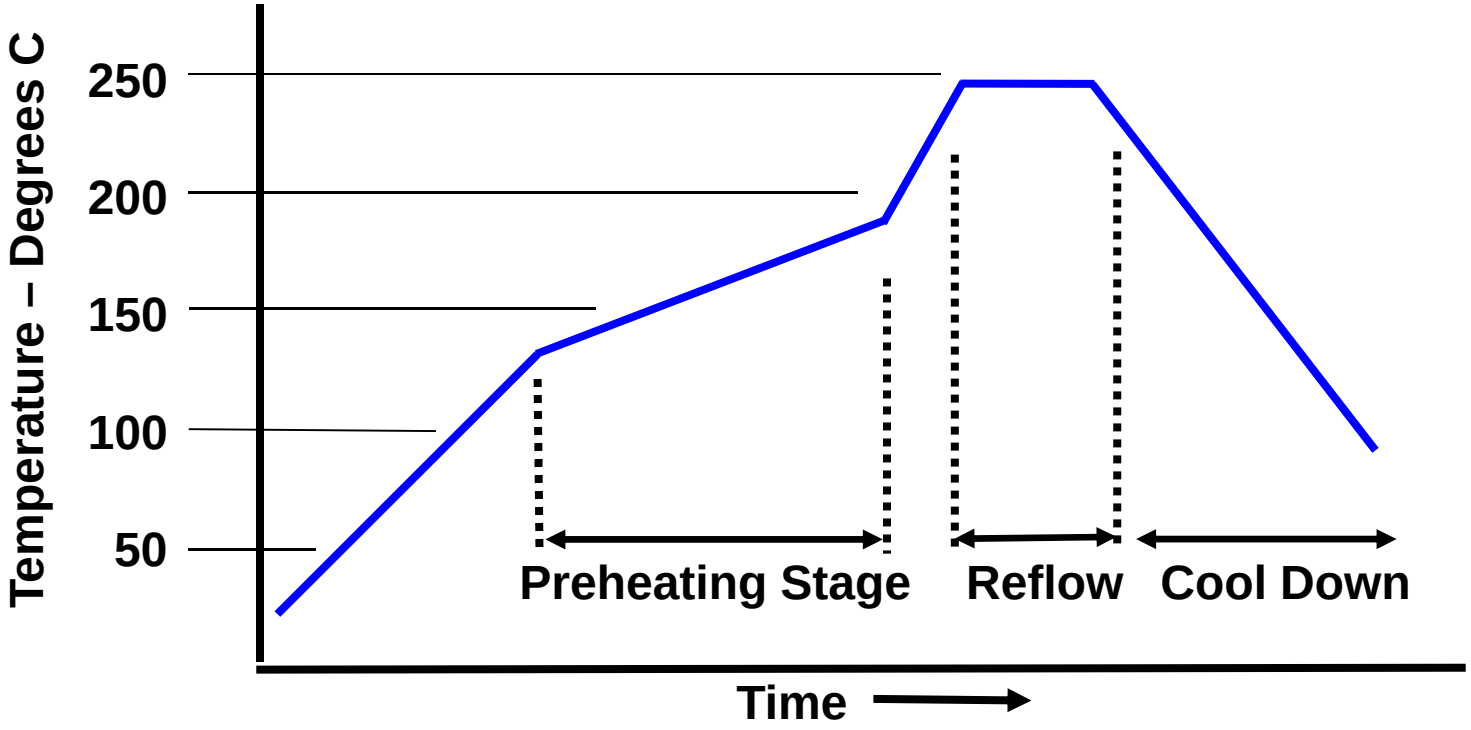
Memory Package
Flux Dipping Reservoir





Ideal Flux Depth = 50-60%

Profile Recommendation for OMAP4xxx (TMV)

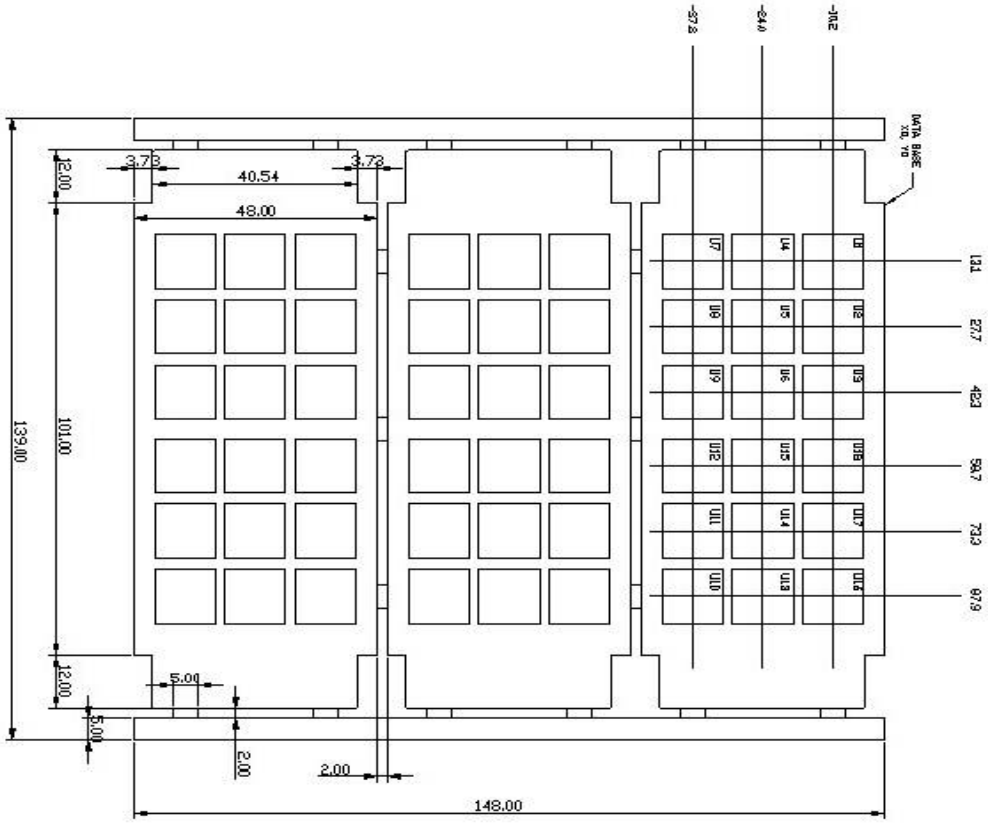


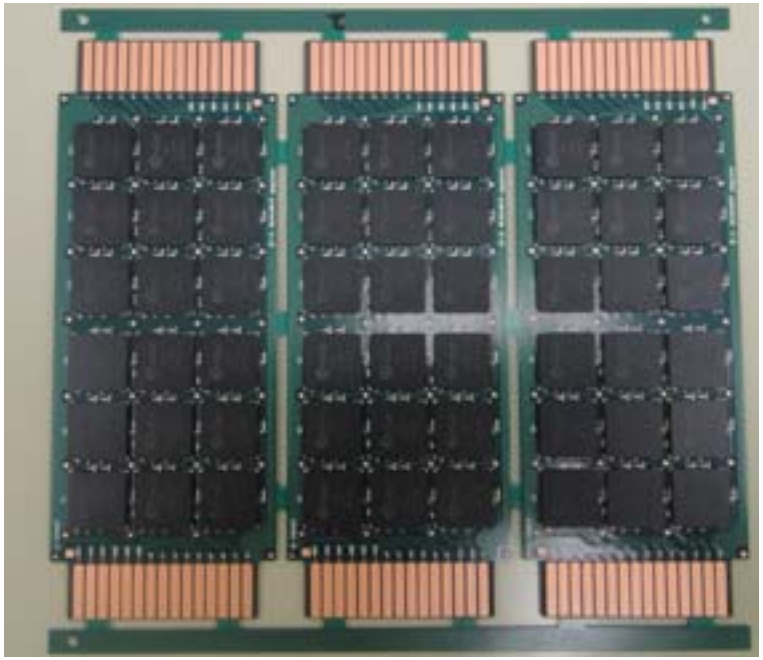
Reflow conditions:

➢ RT to 150˚C	1~3˚C/s
➢ Pre –heat temp(150~200 ˚C)	60~120sec
➢ Time above melting 220˚C	50~80sec
➢ Peak temp	240-250˚C
➢ Cool down rate	2~6˚C/sec (max.)

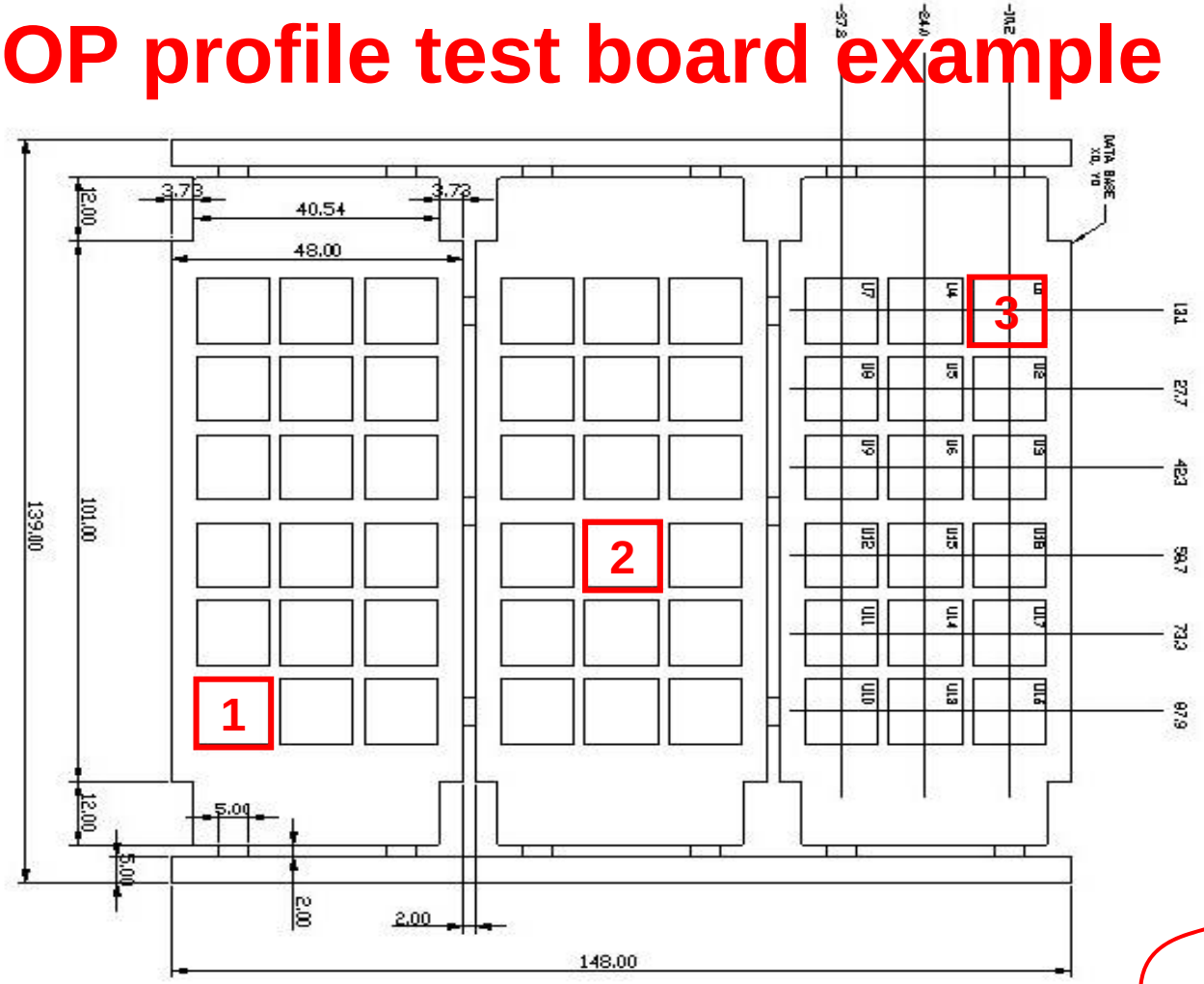
- ✓ Evaluated solder paste:
  - ✓ Shenmao PF-606-P (SAC305)
  - ✓ Tamura TLF-204-19A
- ✓ Evaluated Memory dip flux/paste:
  - ✓ Senju M705-TVA03.9F (Paste)
  - ✓ Senju Deltalux-901K3 (Flux)
- ✓ <700 ppm O2 reflow atmosphere is recommended to provide the widest process window.
- ✓ The real profile must be fine-tuned for each product to meet the optimized soldering results

PCB panel





POP profile test board example



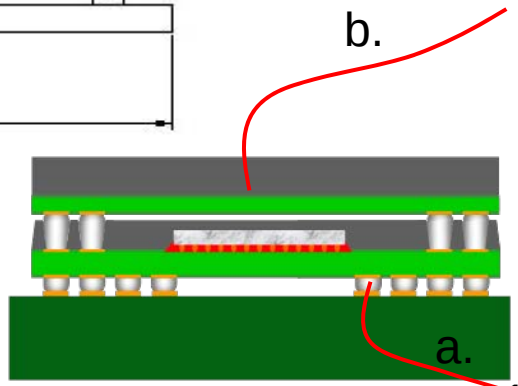
-Thermal couple test locations: see above picture

-Thermal couple test points:

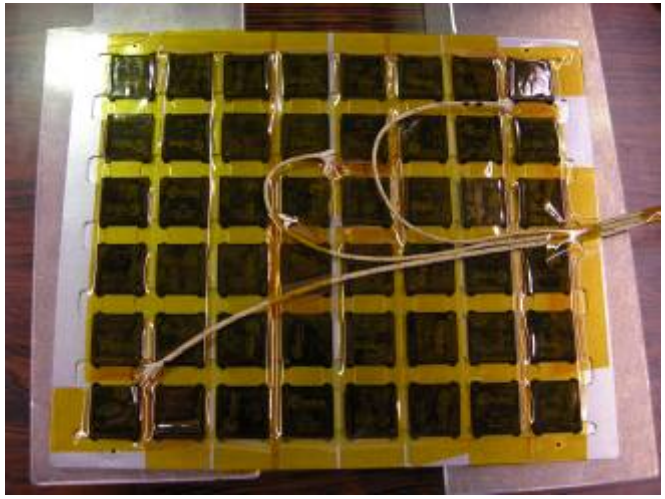
a. The central point btw PCB & OMAP

b. The central point btw OMAP & Memory

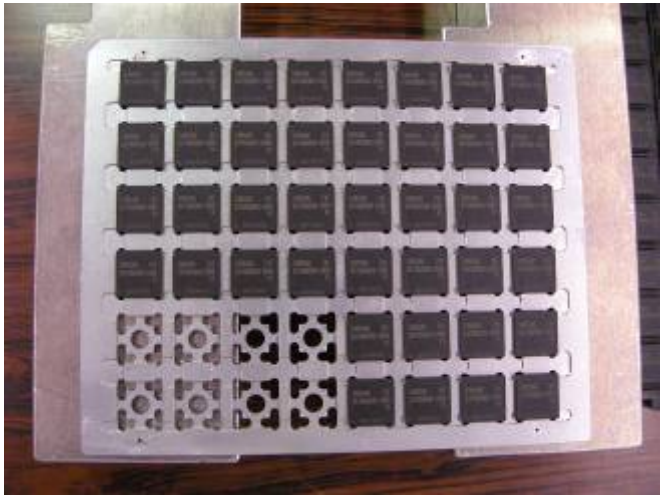
-Total 6 test points



2-pass reflow: Pre-stack tray for FCPOP

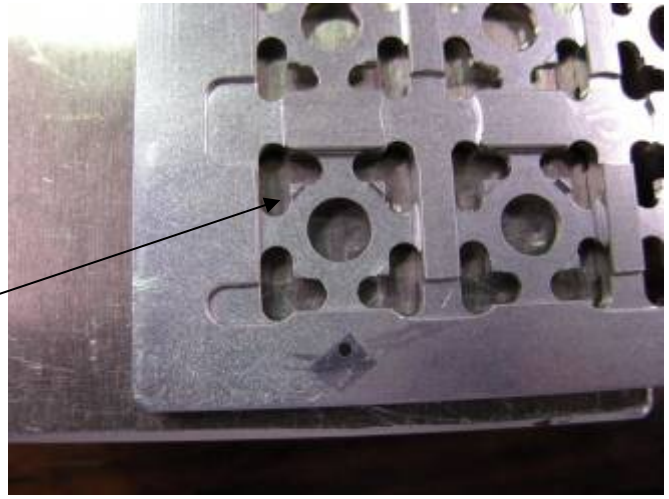


To check temperature profile



Pre-stack tray designed for TI OMAP3430

Bottom POP is supported by
this rib to depopulated ball area



Pre-stack tray designed for TI OMAP3430

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  - ✓Stencil/PCB design guide
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  - ✓SMT experiment examples
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OMAP4xxx SMT Evaluation

Preliminary experiments performed concurrent to package design and material selection

Experiments	1	2	3	4	5	6	7
Dippable mat'l	Senju 529D-1	Senju 529D-1	Senju 529D-1	Senju 529D-1	Senju M705-TVA03.9-F	Senju Deltalux-901K3	Senju Deltalux-901K3
	Flux	Flux	Flux	Flux	Paste	Flux	Flux
Dipping plate depth	170um	170um	170um	170um	140um	170um	160um
Reflow Atmosphere	Air	N2	N2	Air	N2	N2	N2
Reflow preheat time (sec)	80-90	80-90	60-65	60-65	70-80	70-80	70-80
Dwell time for TMV package placement (ms)	300	300	300	300	300	300	300
Dwell time for memory package dipping (ms)	300	300	300	300	600	600	300
Dwell time for memory package placement (ms)	300	300	300	300	500	500	500
Sample Size	1635	204	2310	1700	972	216	700
Rejects	114	0	5	37	0	3	8
Yield	93%	100%	100%	98%	100%	99%	99%

Total Air Atmosphere	
Sample Size	3335
Rejects	151
Yield	95.5%

Total N2 Atmosphere	
Sample Size	4402
Rejects	16
Yield	99.6%

Summary:

- **Nitrogen atmosphere better than air**
- **Senju 901K3 better in air than Senju 529D-1***
- **Dipping depth too deep***

*reference follow up tests in this report

OMAP4xxx DOE Experiments

OMAP4xxx DC (TMV) SMT Evaluation
DOE1

DOE1 Set Up

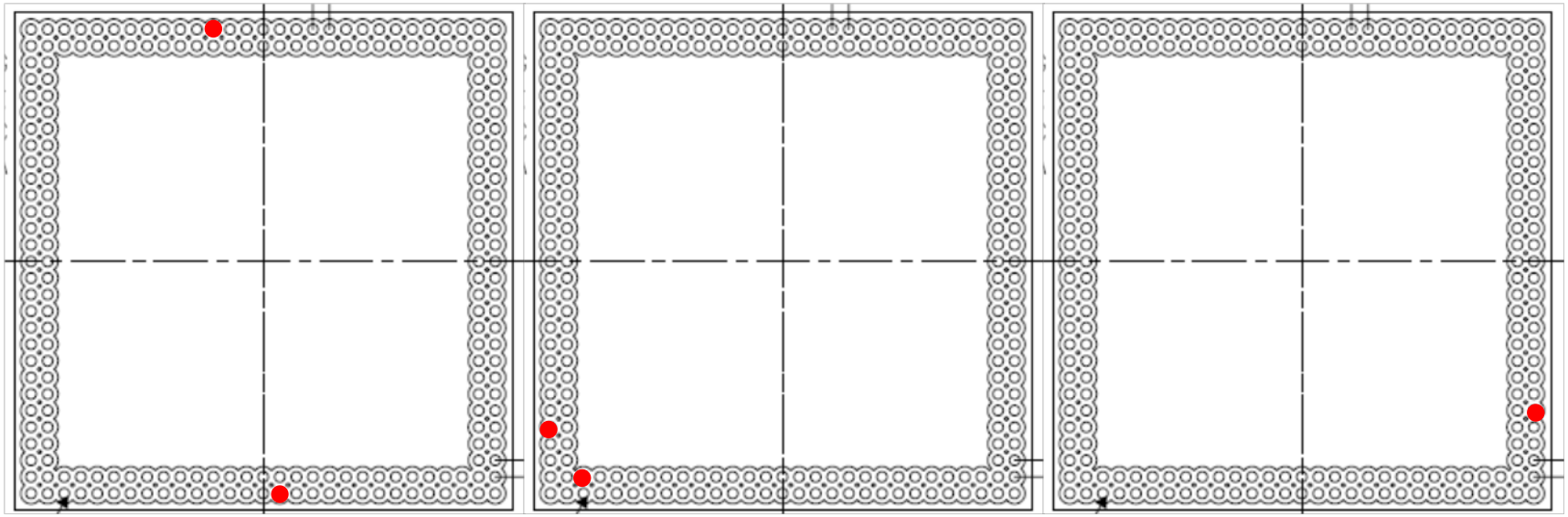
	Flux Dipping	Paste Dipping
OMAP4 Package	OMAP4 CBS Daisy Chain	OMAP4 CBS Daisy Chain
Memory Package	Mock Up	Mock Up
SMT Board	NSMD Pads	SMD Pads
Bottom BGA Paste	Shenmao PF-606-P (SAC305)	Shenmao PF-606-P (SAC305)
Top BGA Flux or Paste	Senju Deltalux-901K3 **(No-Clean dipping flux)**	Senju M705-TVA03.9F **(SAC305, No-Clean dipping paste)**
Solder Stencil	Laser and electro-polished	Laser and electro-polished
Thickness (um)	80	80
Shape	Round	Round
Outer Four Rows Diameter (um)	250	250
Inner Rows Diameter (um)	200	200
Memory Package Dipping Depth (um)	120 - 140um	See other table
Reflow Profile		
Pre-heat time	70-80 sec	70-80 sec
Time above Liquid	65 - 75 sec	65 - 75 sec
Peak temp and time	245-250oC	245-250oC
Reflow Atmosphere	Nitrogen (700 O2 ppm)	Nitrogen (700 O2 ppm)
Sample Size	540 packages	270
Yield		
Opens (DC net test)	0/540	See other table
Shorts (X-Ray)	0/540	See other table

DOE1 Results

	Run 1	Run 2
	Flux Dipping	**Paste Dipping**
Memory Ball Height	190um	190um
Top BGA Flux or Paste	Senju Deltalux-901K3 **(No-Clean dipping flux)**	Senju M705-TVA03.9F **(SAC305, No-Clean dipping paste)**
Warm up time	> 8 hours	See below table
Memory Package Dipping Depth (um)	120 - 140um	See below table
Sample Size	540 ea	270ea
Yield		
Opens (DC net test)	0/540	See below table
Shorts (X-Ray)	0/540	See below table

Run	2-1	2-2	2-3	2-4	2-5
Bottom BGA Paste	Shenmao PF-606-P (SAC305)				
Warm up time	> 18 hours				
Top BGA Paste	Senju M705-TVA03.9F (SAC305, No-Clean dipping paste)				
Warm up time	30 min	> 18 hours			
Memory Package Dipping Depth (um)	140	125	124	122	122
Yield					
Opens (DC net test)	0/54	0/54	0/54	0/54	0/54
Shorts (X-Ray)	54/54	2/54	0/54	0/54	0/54

Top BGA Typical Solder Joint Defects



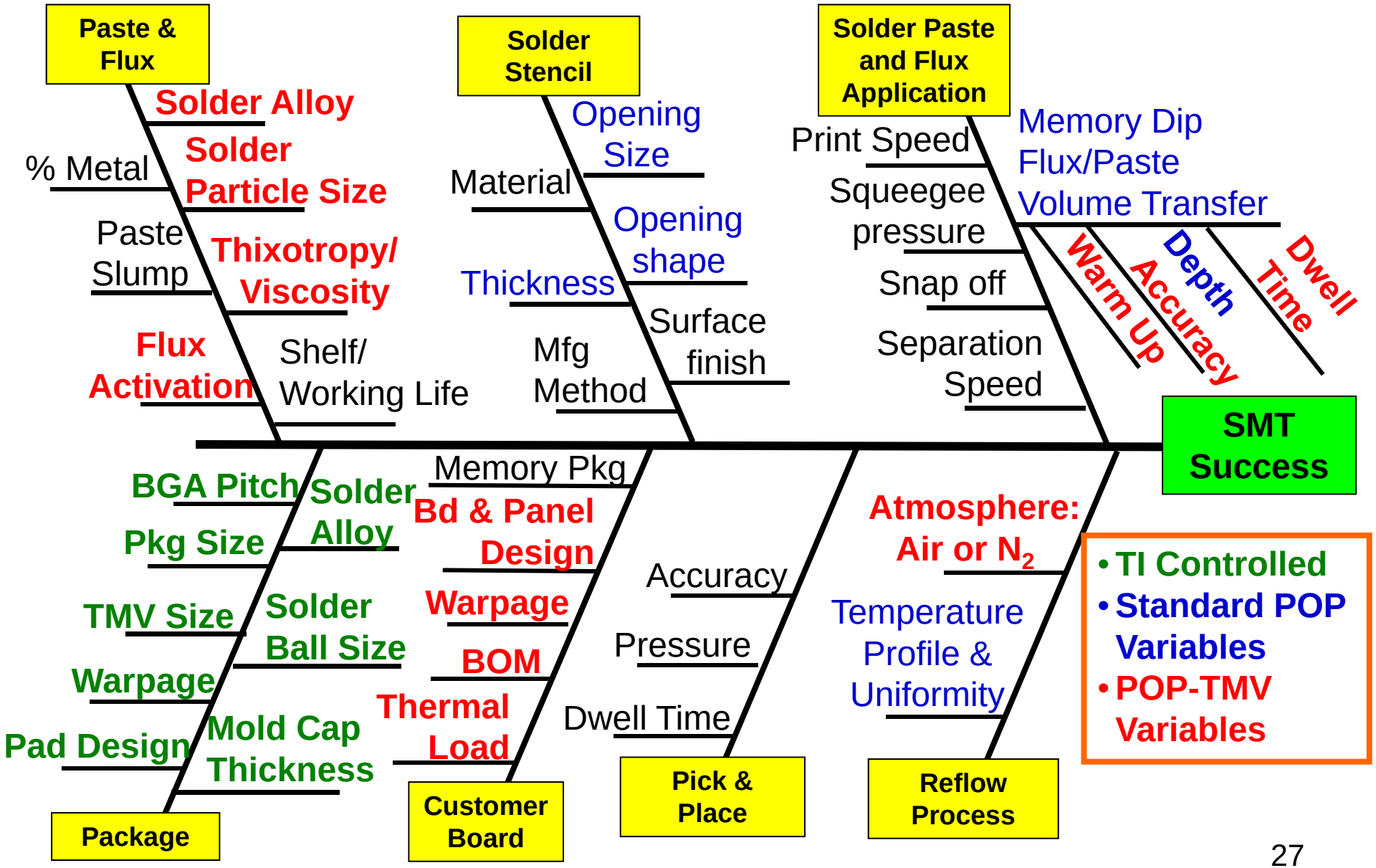
Defect: Random single or double non-wet solder joints

Root Causes:

- Insufficient flux
- OMAP and/or Memory solder ball height and gap variation during the reflow process

Solution: Flux volume transfer control

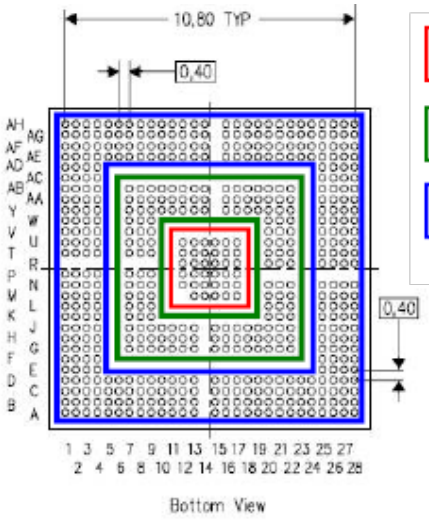
POP SMT Process Variables



OMAP4xxx DC (TMV) SMT Evaluation
DOE2

DOE2 Set up: Screen Print Stencil Design & Reflow Process

Stencil Designs	1	2	3	4	5	6	7	8
Shape	Round 80 Variable, Nano	Round 80 Variable	Round 80	Square 80 Uniform	Square 80 Variable	Square 80 variable Nano	Round 100 Uniform	Round 100 Uniform
Thickness (um)	80	80	80	80	80	80	100	100
Zone C	250	250	250	250	250	250	210	255
Zones A & B	200	200	250	250	200	200	210	255
Opening Ratio								
Zones C	0.78	0.78	0.78	0.78	0.78	0.78	0.53	0.64
Zone A & B	0.63	0.63	0.78	0.78	0.63	0.63	0.53	0.64



Zone A: Center Array

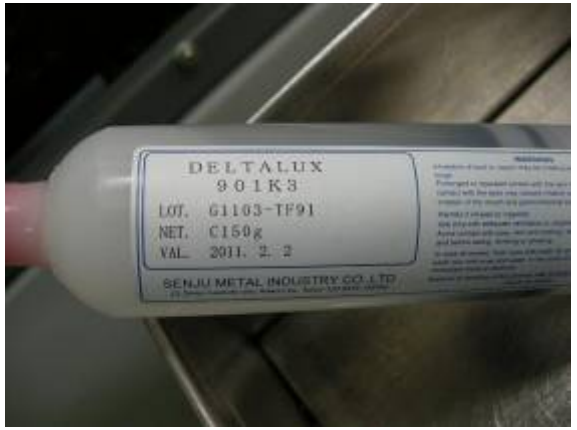
Zone B: Middle Array

Zone C: Outer Array

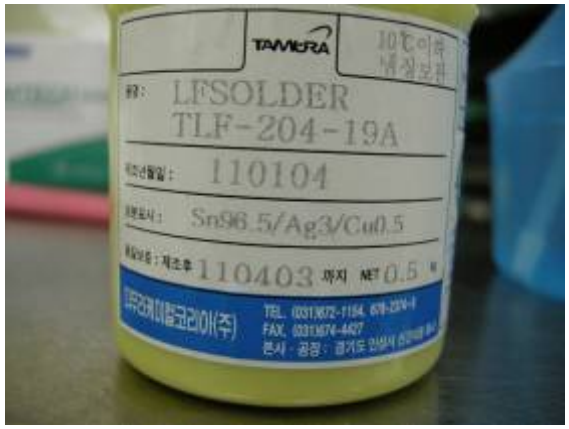
Reflow Profiles	Option 1	Option 2	Option 3
Preheat Zone			
Temperature	R/T-120C	R/T-120C	R/T-120C
Time	70	90	110
Soak Zone			
Temperature	120-180c	120-180c	120-180c
Time	90	110	130
Reflow Zone			
Peak Temperature	235	240-245	245-250
Time above Liquid	60	80	100
Cooling Zone	3°/sec	3°/sec	3°/sec

DOE2: Solder Paste and Flux

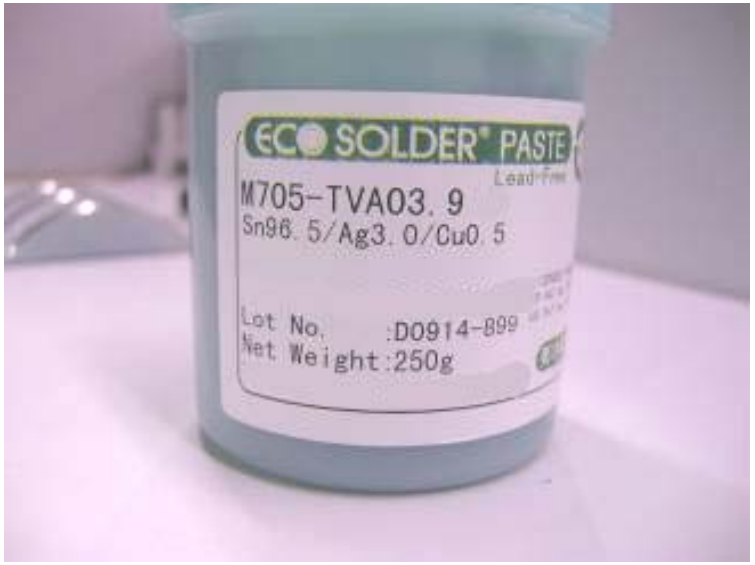
Flux for memory dipping:
Senju DELTALUX 901K3



Solder paste for POP mount:
Tamura TLF-204-19A



Solder paste for memory dipping:
Senju M705-TVA03.9-F

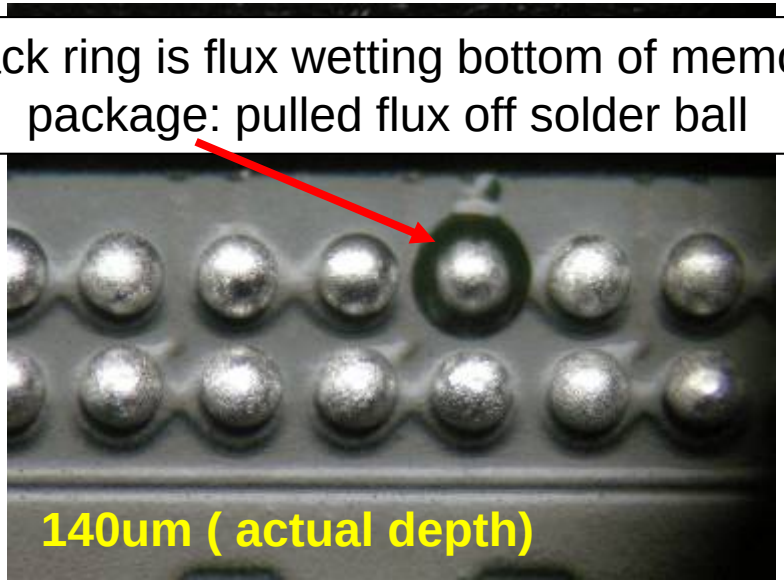


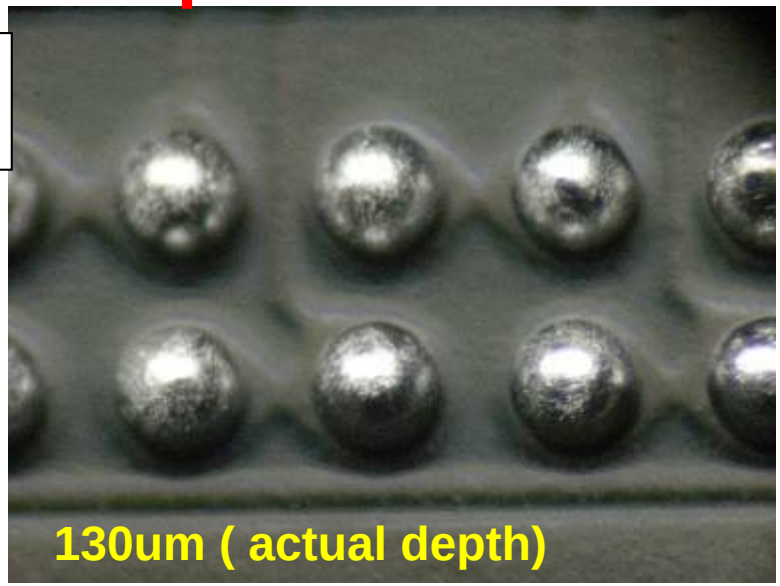
DOE2 Results

Legs	Stencils					POP Memory Process		Reflow Profile			Reflow Atmosphere		Qt'y	Opens		Shorts	Yield	
	1	4	5	7	8	Dipping Material	Dipping Depth (um)	A	B	C	Air	N_2 <700ppm O_2		Bottom	Top	Any	Bottom	Top
1						Paste: Senju M705-TVA03.9F	105						216	0	0	0	100%	100%
2							140						216	0	0	0	100%	100%
3							180						54	0		54	100%	0%
4						Flux: Senju 901K3	140						216	0	76	0	100%	65%
5							130						216	0	0	0	100%	100%
6							130						216	1	1	0	99.5%	99.5%
7							130						216	0	1	0	100%	99.5%
8							130						216	0	0	0	100%	100%
9							130						216	0	216	0	100%	0%
10							130						108	0	108	0	100%	0%
11							130						108	0	1	0	100%	99%
12							130						216	0	216	0	100%	0%
13							130						108	0	102	0	100%	6%
14							130						108	0	0	0	100%	100%
15 (15 air bake, 150oC, 8 hrs)							130						108	0	108	0	100%	0%
16 (15 air bake, 150oC, 8 hrs)							130						108	0	0	0	100%	100%
17-1	N/A (Pre-Stack)					Paste: Senju M705-TVA03.9F	140						108	N/A	N/A	N/A	N/A	N/A
17-2	N/A (Pre-Stack)					Flux: Senju 901K3	130						108	N/A	N/A	N/A	N/A	N/A
17-1a						17-1 pre-stack							108	0	0	0	100%	100%
17-2b						17-2 pre-stack							108	0	0	0	100%	100%
												Total	2862					

Memory Dipping Defect Example

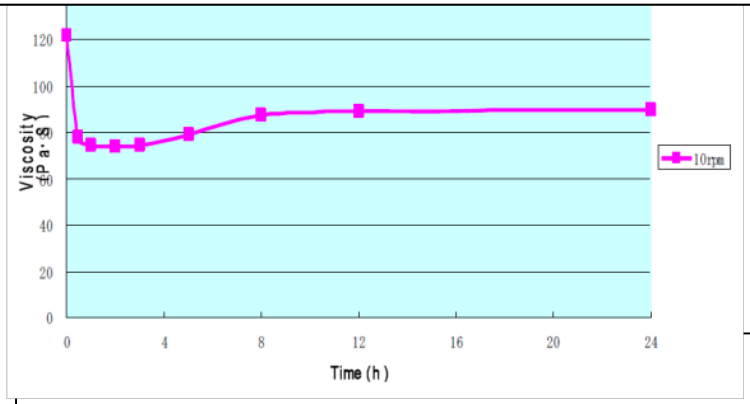
Black ring is flux wetting bottom of memory package: pulled flux off solder ball





Flux Legs	Flux Dipping Mat'l	Dipping Depth	Reflow Peak Temp (oC)	Reflow Atmosphere	Package Quantity	Yield
1	Senju Deltalux-901K3	140um	240-245	N_2 (<700ppm O_2)	216	65%
2	Senju Deltalux-901K3	130um	240-245	N_2 (<700ppm O_2)	216	100%

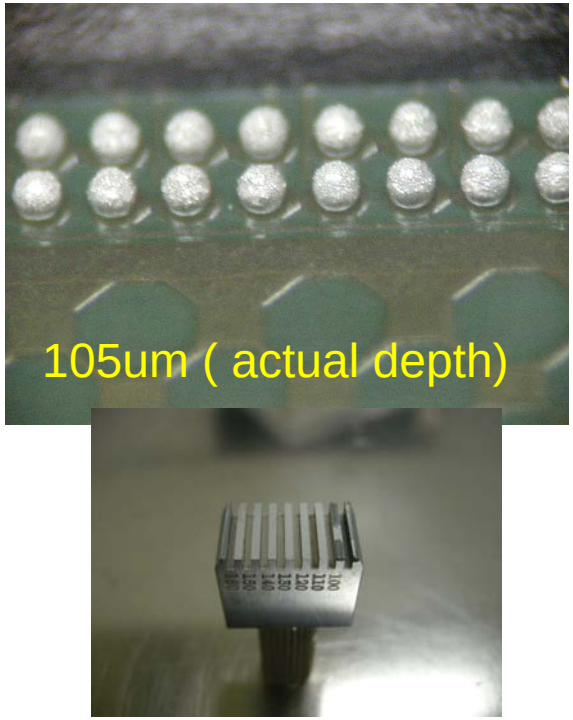
Flux viscosity with continuous stirring

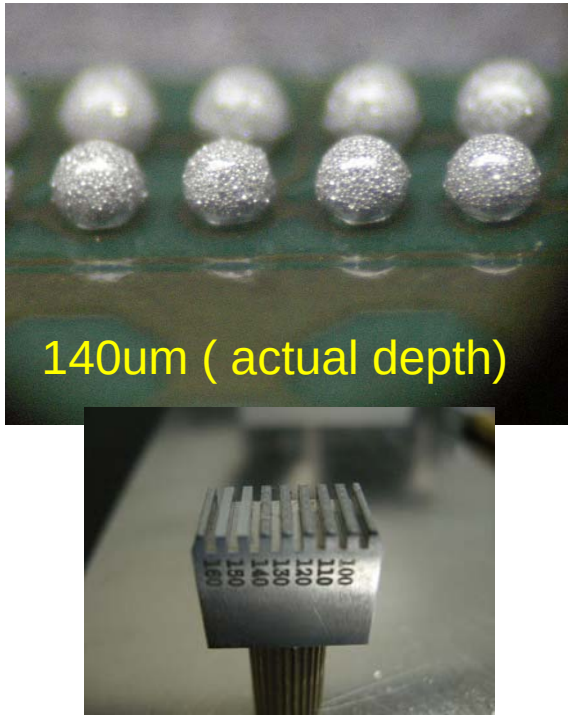


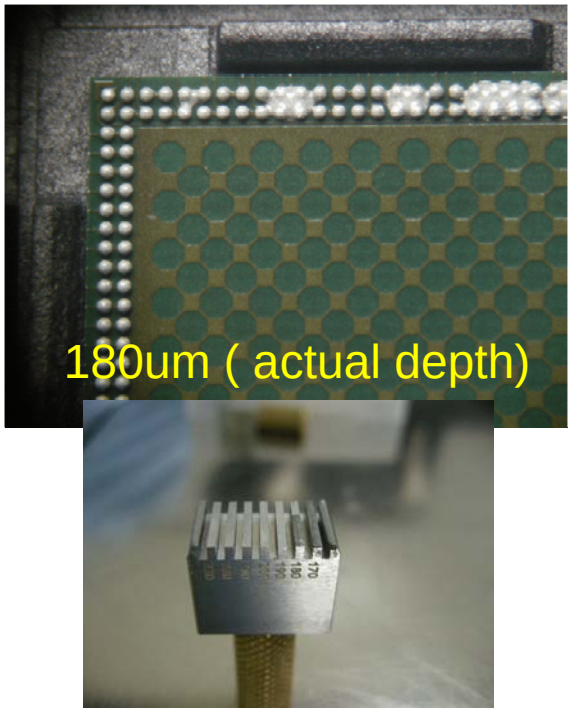
Flux transfer to memory package is critical:

- Type of flux
- Viscosity of flux
- Dipping depth
- Dwell time of package in flux tray

Paste Dipping Experiment Result







Paste Legs	Paste Dipping Mat'l	Dipping Depth (um)	Reflow Peak Temp (oC)	Reflow Atomosphere	Package Q'ty	Yield
1	Senju M705-TVA03.9F	105	240-245	N_2 (<700ppm O_2)	216	100%
2	Senju M705-TVA03.9F	140	240-245	N_2 (<700ppm O_2)	216	100%
3	Senju M705-TVA03.9F	180	240-245	N_2 (<700ppm O_2)	54	0%

DOE2 Result

Summary:

- Bottom BGA yield robust vs. stencil design
- Top BGA yield sensitive to flux dipping process
  - Depth
  - Viscosity
  - Dwell time
- Top BGA dipping in paste successful: verification required
- Nitrogen atmosphere (<700ppm O_2) required in this test
- Experiments will continue to define assembly capability in an Air reflow atmosphere

OMAP4xxx DC (TMV) SMT Evaluation
DOE3

DOE3 Set up:

Reflow Profile	
Preheat Zone	
Temperature	R/T-120C
Time	90
Soak Zone	
Temperature	120-180c
Time	110
Reflow Zone	
Peak Temperature	240-245
Time above Liquid	80
Cooling Zone	3°/sec

Stencil Design	
Shape	Round 80 Variable
Surface Finish	Laser Job nano coating
Thickness (um)	80
Opening Diameter(um)	
Zone C	250
Zones A & B	200
100% Volume Transfer Rate	
Zones C (um^3)	3926991
Zone A & B (um^3)	2513274
Opening Ratio	
Zones C	0.78
Zone A & B	0.63

Material in DOE3		Recommended reflow atmosphere	Notes
Paste	Senju M705-TVA03.9K	Air	[Halogen Free ROLO (<500ppm) per JSTD-004A, No-Clean Dip Paste]
Paste	Senju TVA 107K	Air	[Halogenated ROL1 per JSTD004A, No-Clean Dip Paste]
Flux	Senju Deltalux 529D-1	Air	[Halogenated ROL1, No-Clean Dip Flux]
Flux	Senju Deltalux-GTN68-HF	Air	[Halogen Free ROLO (<500ppm) per J-STD004A/B, No-Clean Dip Flux]

DOE3: Results

DOE Leg	Bottom BGA Printing Material	Memory Dipping Mat'l		Dipping Depth (Actual depth)	Dipping Dwell Time (ms)	With EMI Shield	Reflow		Q'ty		# Opens	# Shorts	Yield %
							Air	N2 (O_2<700 ppm)	Panels	PKGs			
1	Tamura TLF-204-19A	Paste	Senju TVA 107K	130	600	No			4	216	1	0	99.5
2	Tamura TLF-204-19A	Paste	Senju TVA 107K	130	900	No			19	1000	0	0	100
3	Tamura TLF-204-19A	Paste	Senju M705-TVA03.9K	130	600	No			1	54	24	0	56
4	Tamura TLF-204-19A	Paste	Senju M705-TVA03.9K	130	900	No			1	54	19	0	65
5	Tamura TLF-204-19A	Paste	Senju M705-TVA03.9K	130	600	No			1	54	0	0	100
6	Tamura TLF-204-19A	Paste	Senju M705-TVA03.9K	130	900	No			1	54	0	0	100
7	Tamura TLF-204-19A	Flux	Senju Deltalux 529D-1	130	600	No			1	54	13	0	76
8	Tamura TLF-204-19A	Flux	Senju Deltalux 529D-1	130	900	No			1	54	22	0	59
9	Tamura TLF-204-19A	Flux	Senju Deltalux-GTN68HF	130	600	No			4	216	1	0	99.5
10	Tamura TLF-204-19A	Flux	Senju Deltalux-GTN68HF	130	900	No			19	1000	0	0	100
11	Tamura TLF-204-19A	Flux	Senju Deltalux-GTN68HF	130	900	Yes			3	18	0	0	100
12*	Tamura TLF-204-19A	Flux	Senju Deltalux-GTN68HF	130	900	No			2	108	108	0	0
13*	Tamura TLF-204-19A	Paste	Senju TVA 107K	130	900	No			2	108	108	0	0
								Totals	59	2990			

*Preconditioned: 150C for 1.5 hrs in Air, followed with 8 hrs at 85RH/85C

DOE3 Result

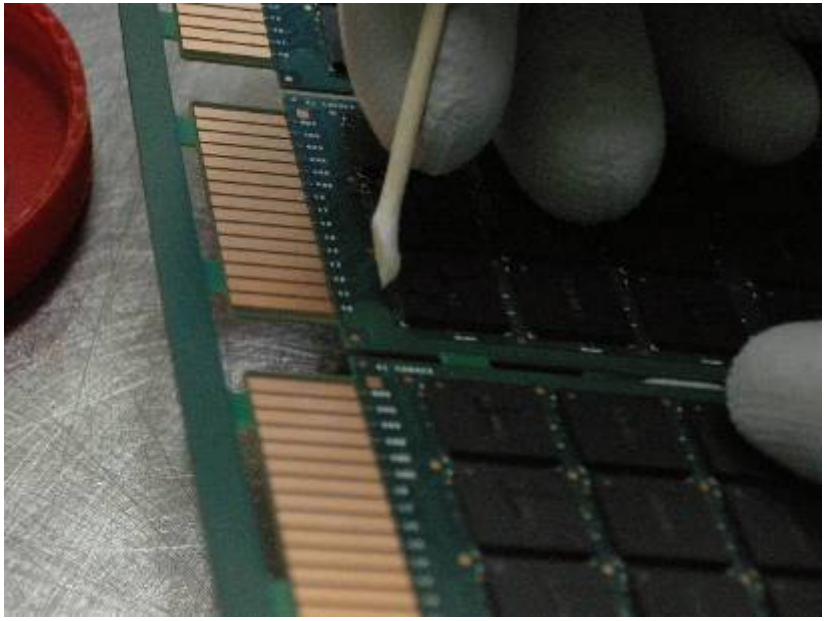
Summary:

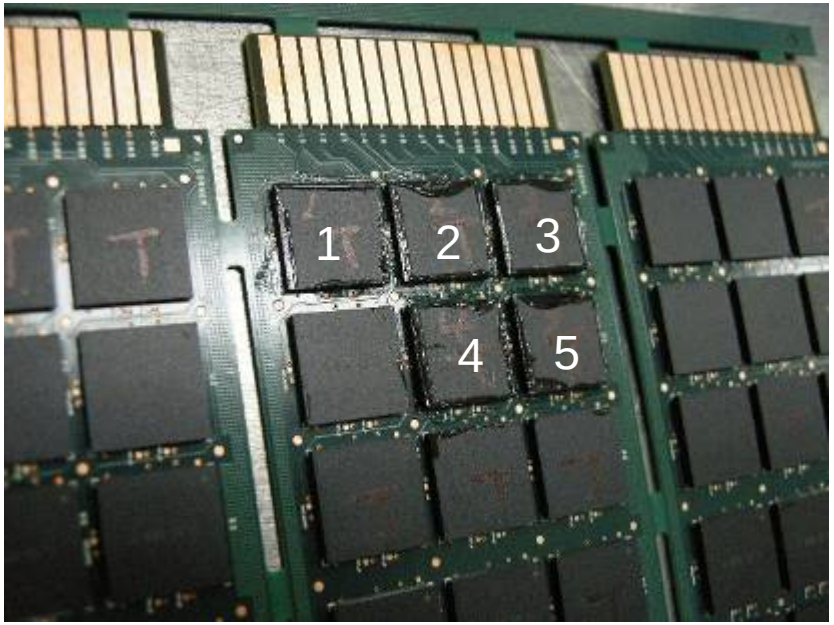
- Flux and Paste chemistry and rheology are critical factors for use in an air reflow atmosphere
- Time out of refrigeration and time worked in dipping tray affects coating uniformity
- Dipping time change from 600ms to 900ms improved yield
- A paste that did not work in air worked in nitrogen reflow atmosphere
- Bottom BGA process continues to be robust
- Pre-conditioned parts shifted and yielded zero bottom BGA connections: X-ray of top BGA looked normal but unable to test due to lack of connection through bottom BGA

Appendix

- ✓A1: Through molded via solder rework methods
  - **Brush with flux repair method**
  - Manual rework method
- ✓A2: X-ray examples
- ✓A3: Screen print material and reflow equipment examples
- ✓A4: Package warpage affect examples

Brush with flux for repair in TMV level (1)

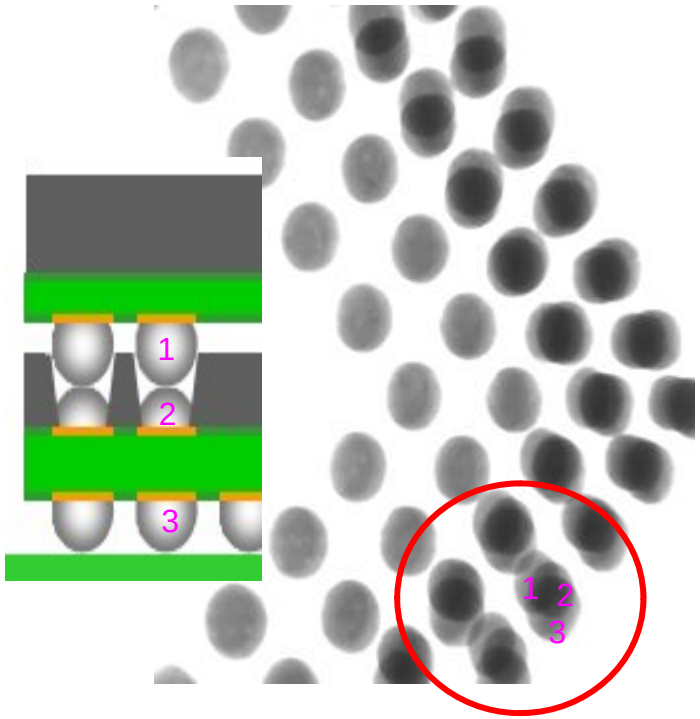




-Use cotton swab to apply adequate flux at the side-walls of defective POP.
-Reflow then Check in X-ray (see next slide) & O/S test.

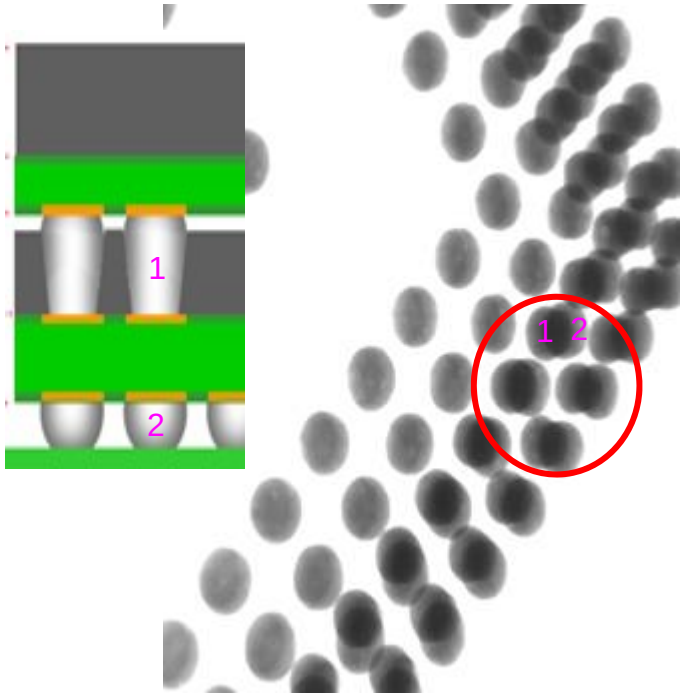
Evaluate samples			Test result (Xray, O/S)	
Size	Flux type	Repair level	OK	NG
5	Senju 529D-1	TMV	5	0

Brush with flux for repair in TMV level (2)



Non-wet Solder Joint

The non-wetting TMV joints show as 3 balls overlapped with bottom BGA ball in X-ray inspection.



Repaired Solder Joint

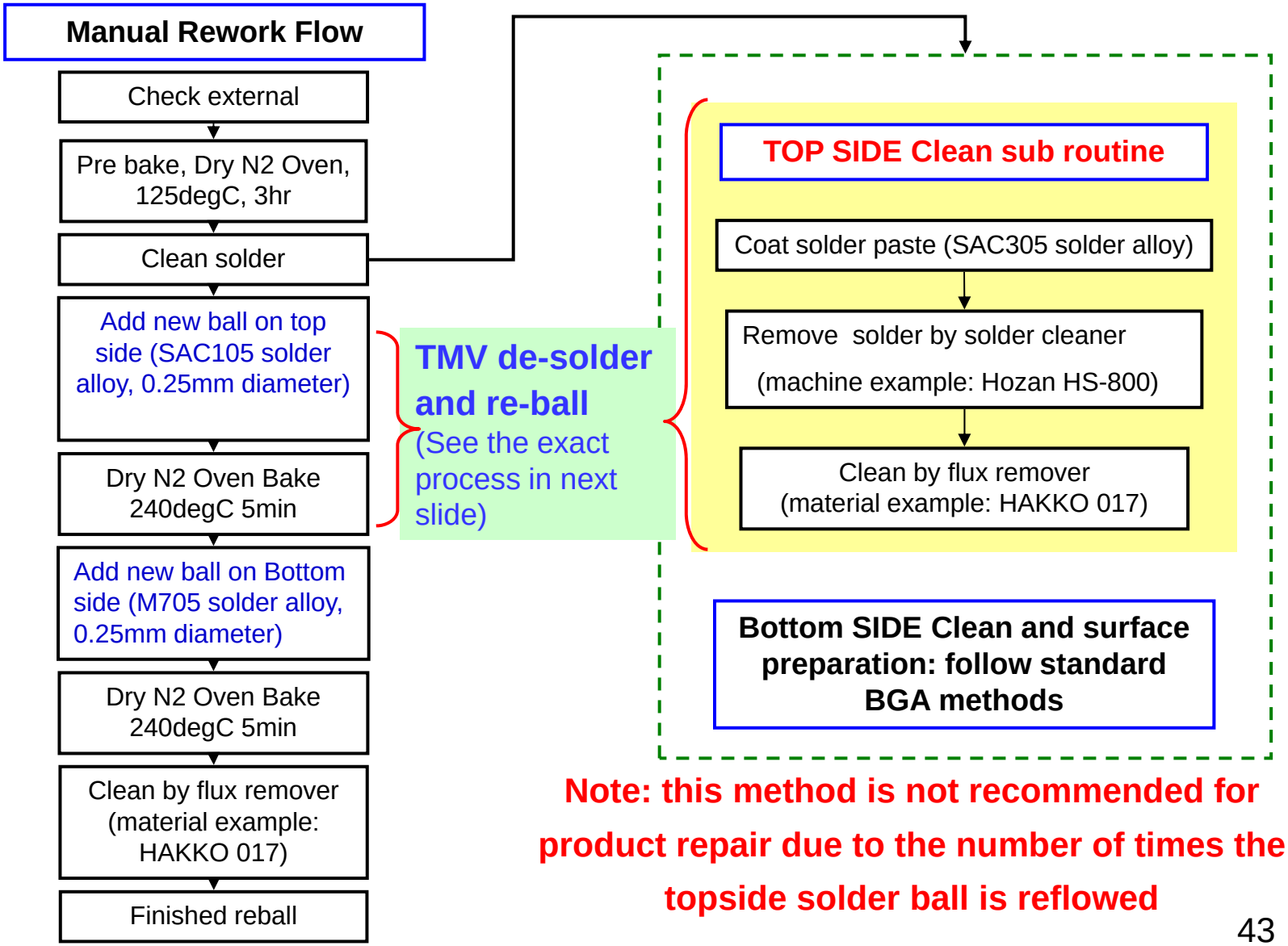
The defect TMV joints are re-healed & show as 2 balls overlapped with bottom BGA ball in X-ray inspection.

Appendix

- ✓A1: Through molded via solder rework methods
  - Basic repair method
  - **Manual rework method**

  Note: this method is not recommended for product repair due to the number of times the topside solder ball is reflowed
- ✓A2: X-ray examples
- ✓A3: Screen print material and reflow equipment examples
- ✓A4: Package warpage affect examples

Process Flow of Manual TMV Rework (1)

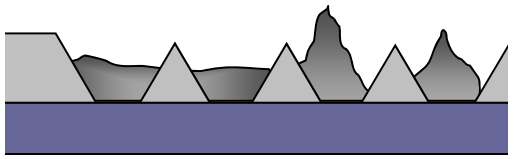


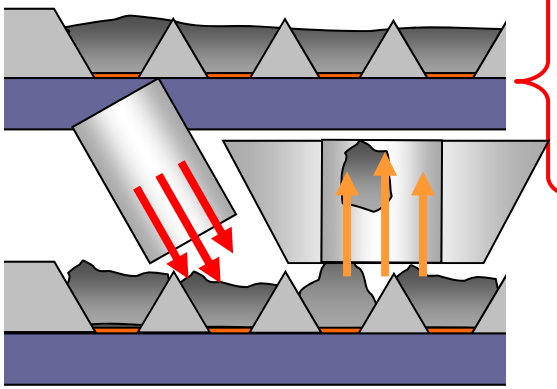
Note: this method is not recommended for product repair due to the number of times the topside solder ball is reflowed

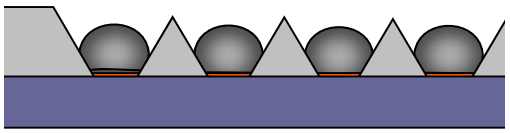
Manual TMV Removal and Re-ball (2)

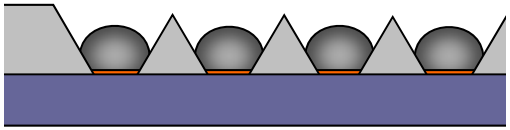
Reball Approach

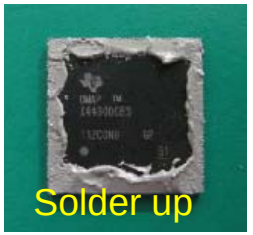
- Customer retur
- Solder up
- De-soldering
- Re-balling
- Bake
- Bottom reball process











• Thicker solder contributes better thermal conduction

• More flux help the solder soften and extract out , vacuum pressure ~80kPa

• Paint with flux and place 0.25mm solder ball and reflow

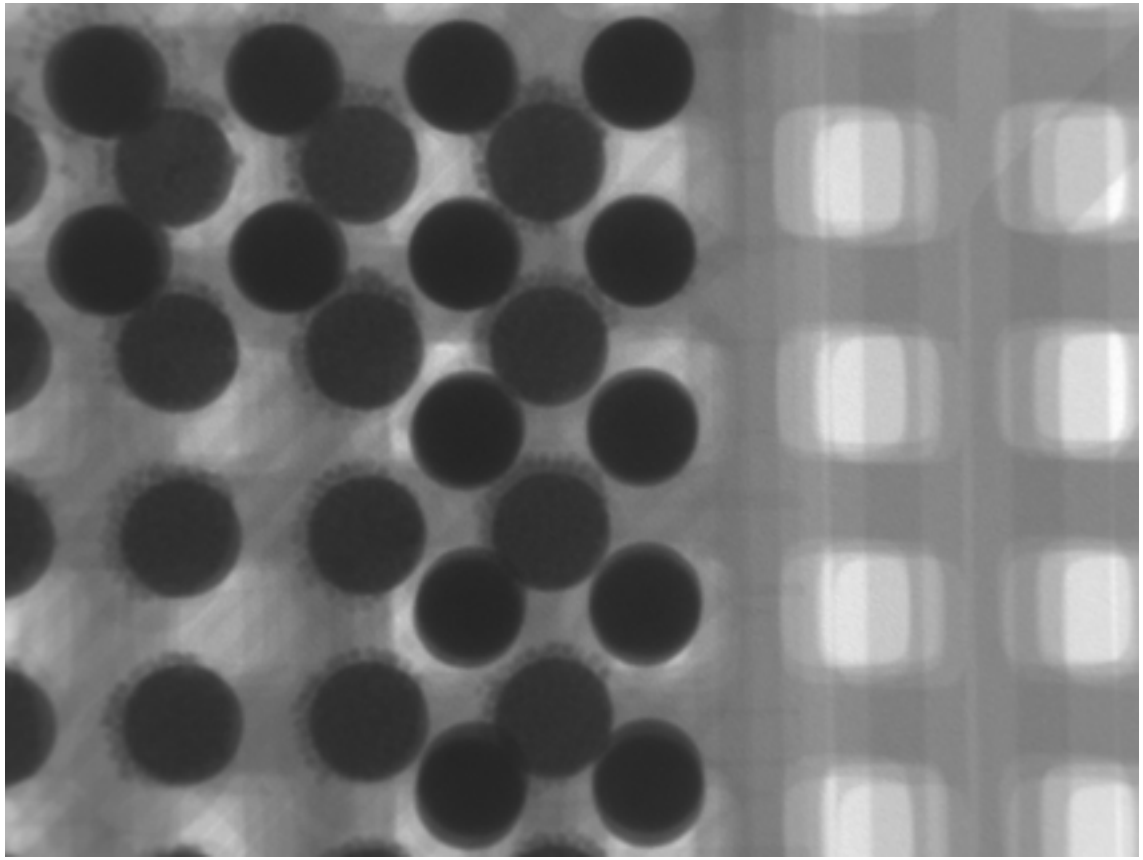
• measure coplanarity by an Equipment

Appendix

- ✓A1: Through molded via solder rework methods
  - Basic repair method
  - Manual rework method
- ✓A2: X-ray examples
- ✓A3: Screen print material and reflow equipment examples A4: Package warpage affect examples

Solder ball analysis by X-ray -1

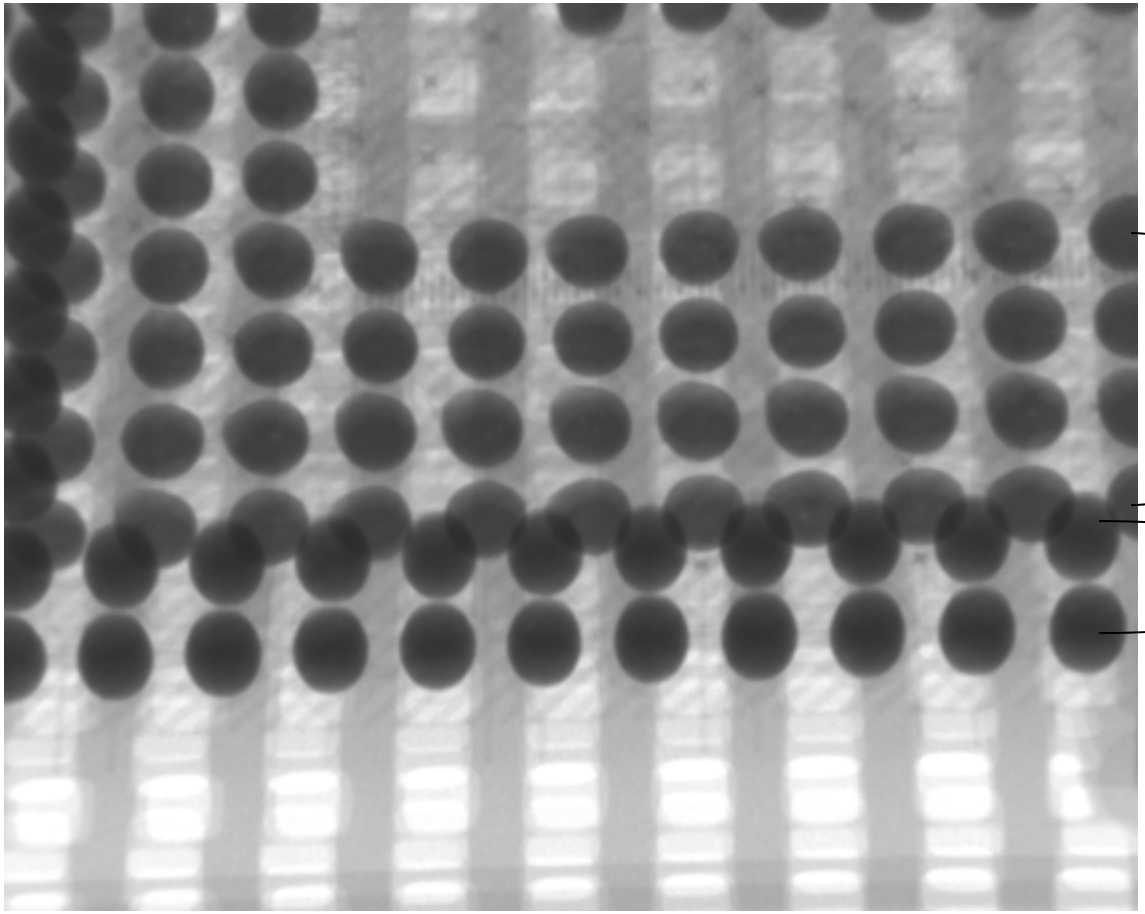
1-pass reflow



Picture: POP and Memory mount on PCB. Before reflow.
Solder paste printing check was good. Memory is mount on POP by flux with good accuracy.

Solder ball analysis by X-ray -2

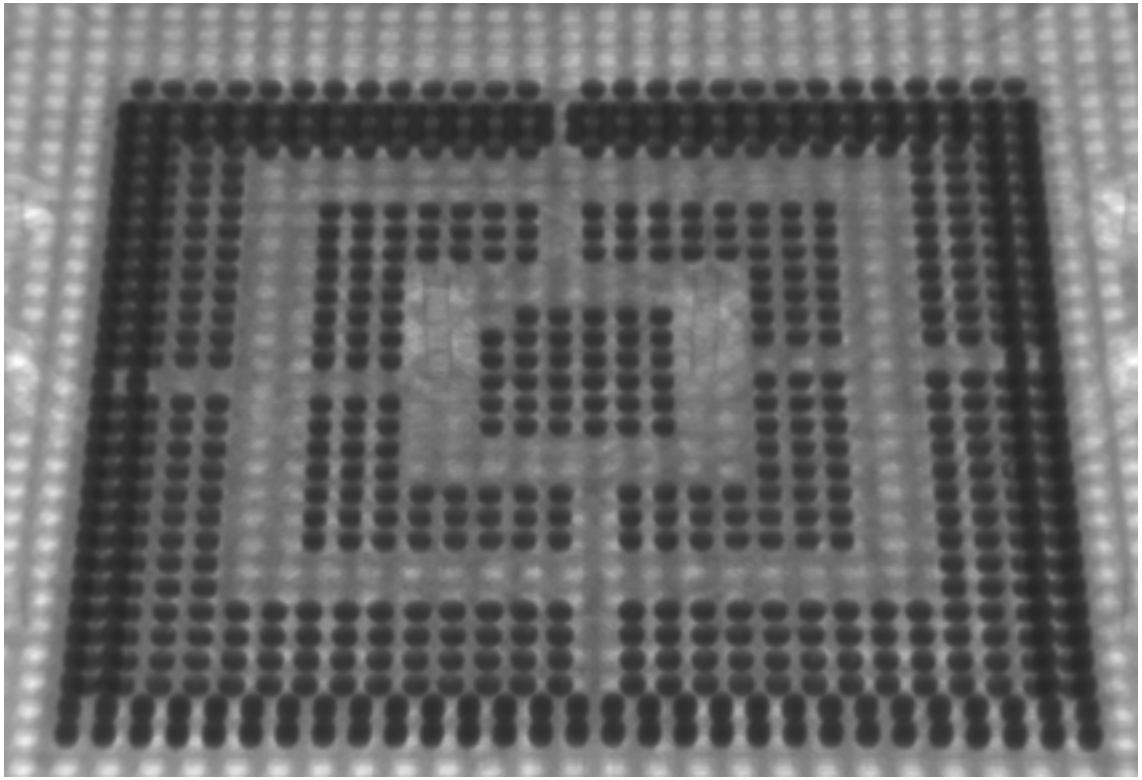
1-pass reflow



Picture: Memory mounted by flux, NSMD board, After reflow
Memory solder ball was jointed with POP showing good barrel shape

Solder ball analysis by X-ray -3

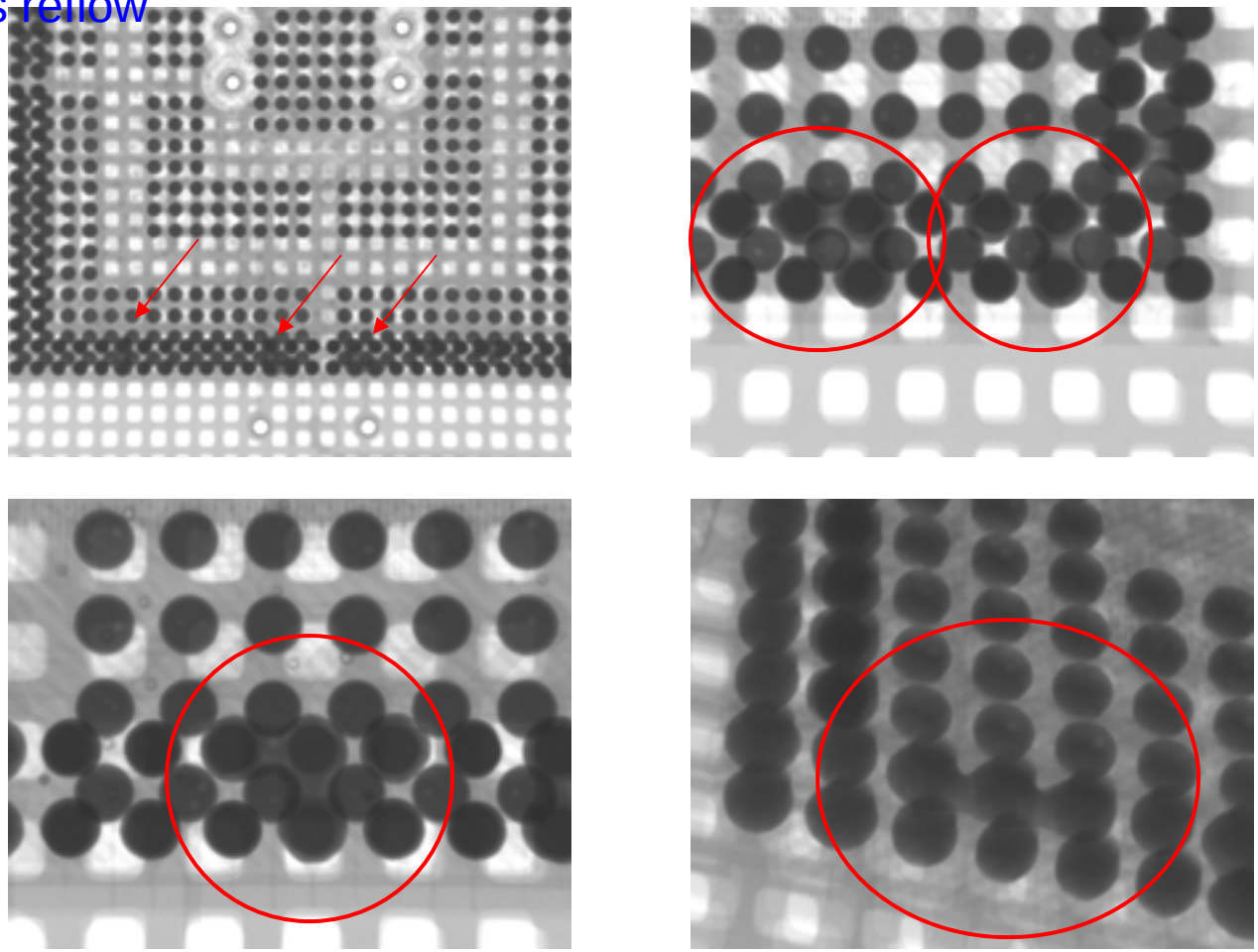
1-pass reflow



Picture: Memory mounted by flux, SMD board, After reflow
Memory jointed with POP with good barrel shape.
No anomaly is found for POP solder balls.

Solder ball analysis by X-ray -4

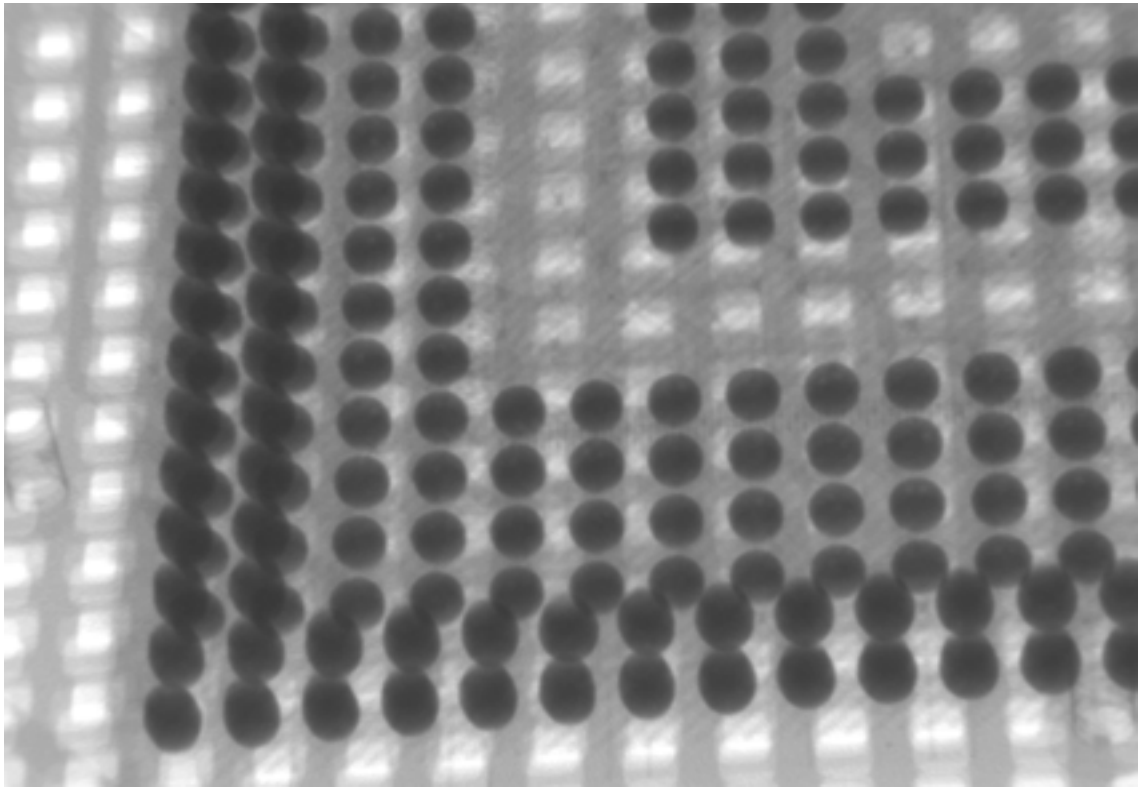
1-pass reflow



Picture: Memory mounted by solder paste, SMD board, After reflow
Excess solder paste caused solder ball short

Solder ball analysis by X-ray -5

1-pass reflow

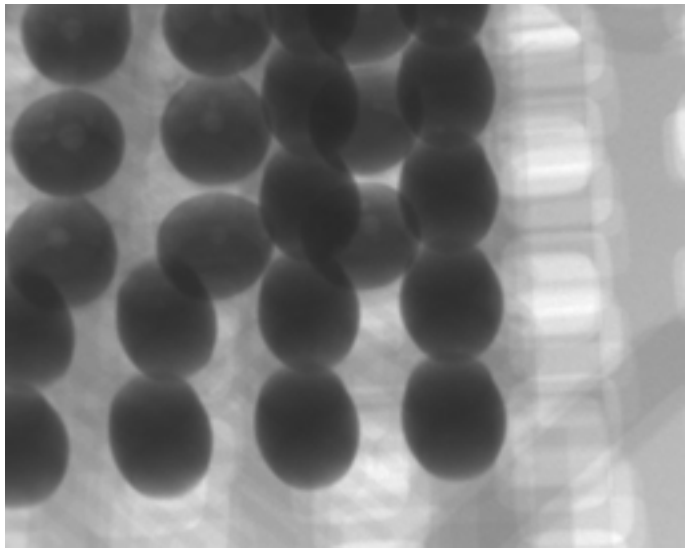


Picture: Memory mounted by solder paste, SMD board, After reflow.
Reduced solder paste dipping depth then solder ball short did not happen

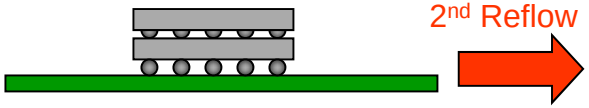
Solder ball analysis by X-ray -6

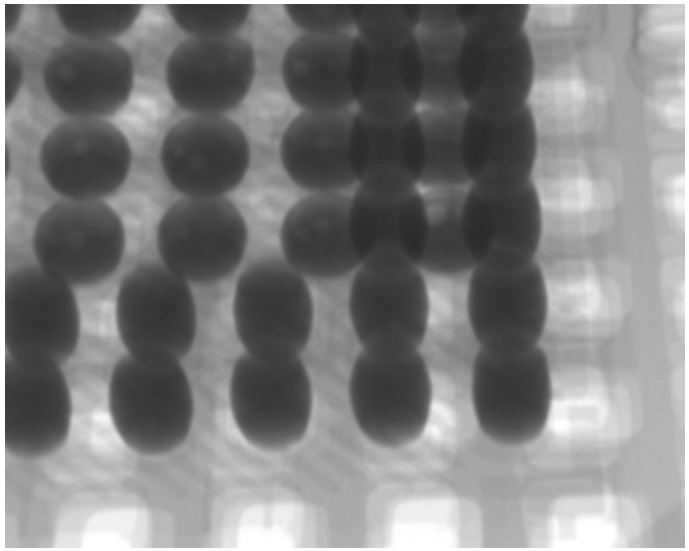
1-pass reflow

2nd reflow result. Run POP+Memory mount board reflow again

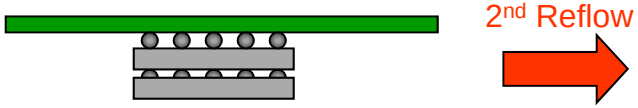


Paste dip, After reflow, SMD pad
Package upward





Paste dip, After reflow, SMD pad
Package downward



Memory solder ball joint did not change by 2nd reflow

Appendix

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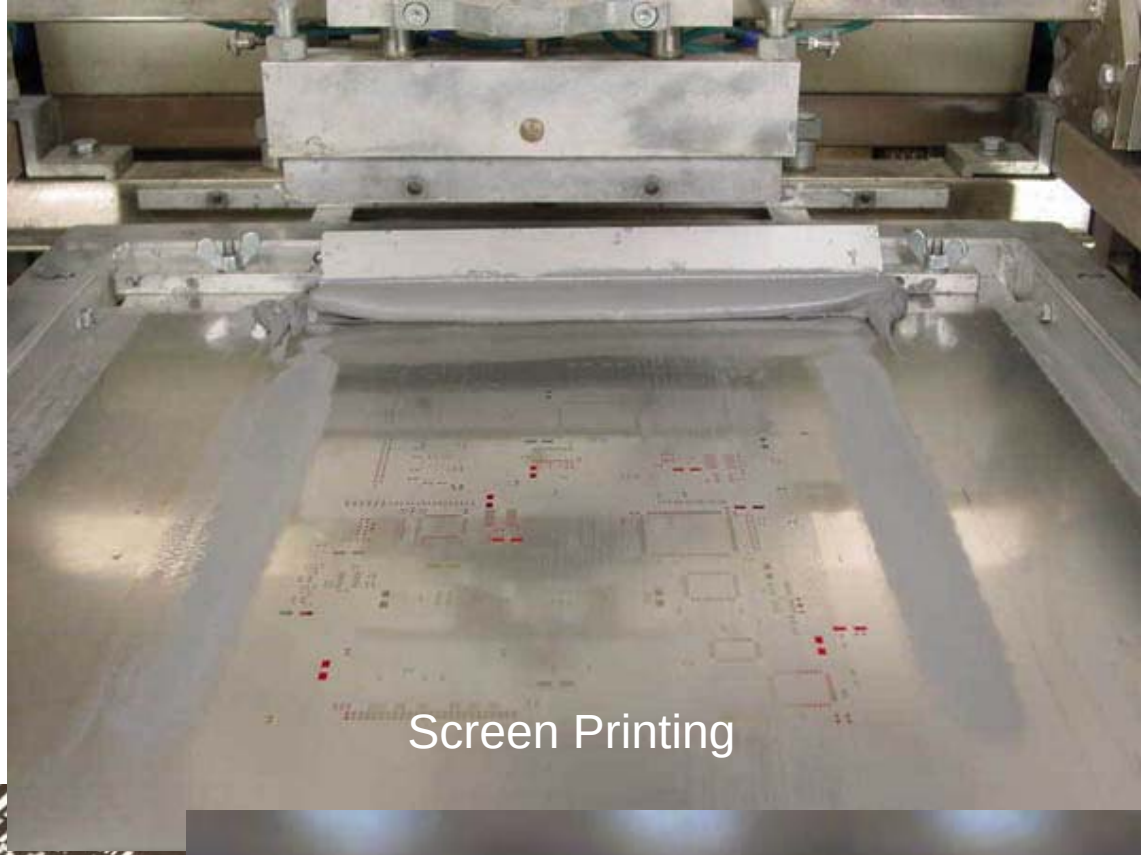
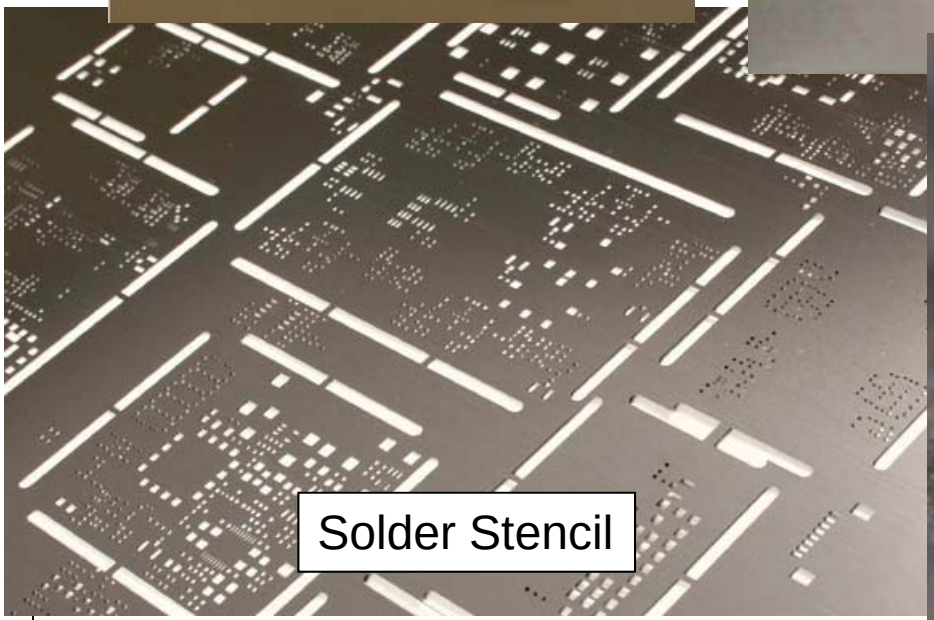
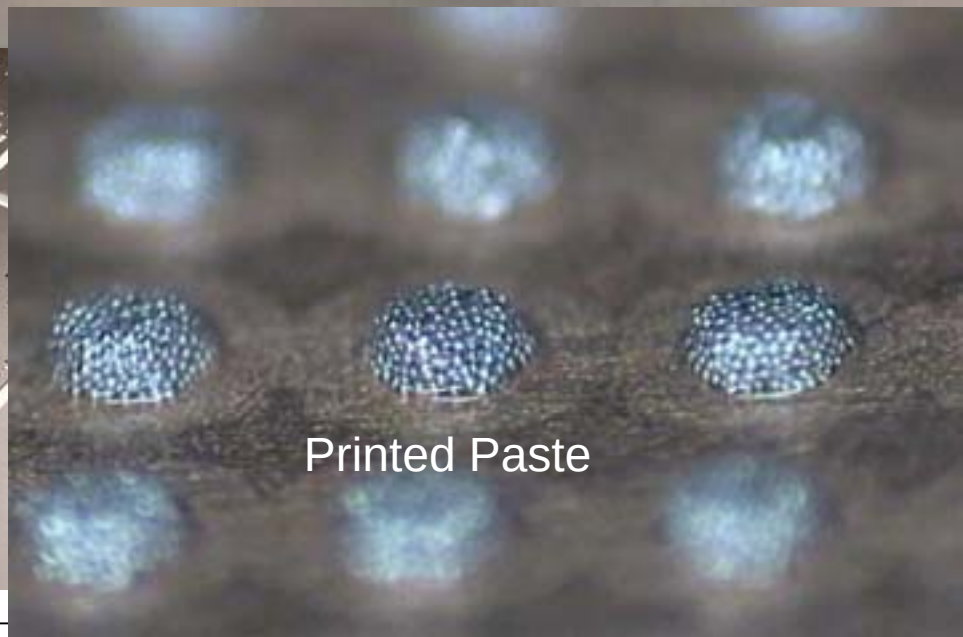
- ✓A4: Package warpage affect examples

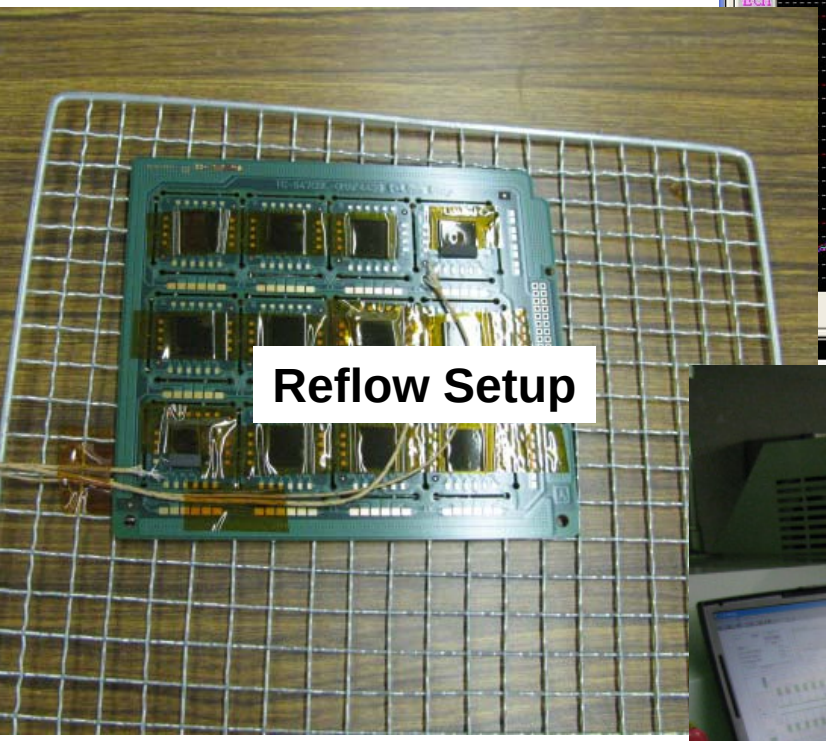

Solder Paste

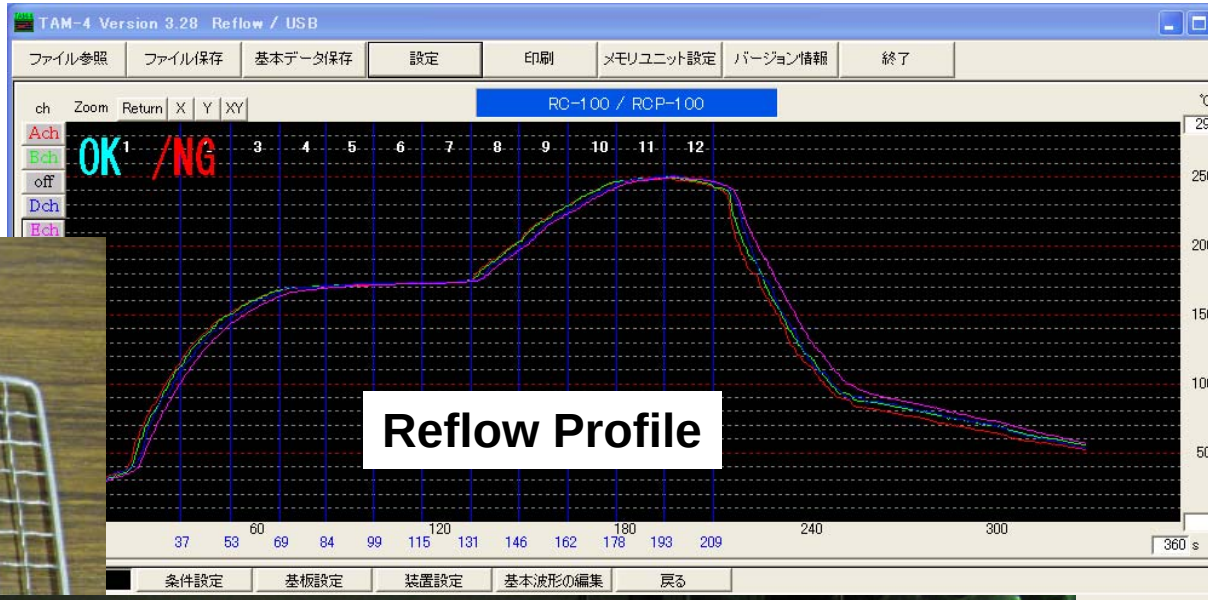

Screen Printing


Solder Stencil


Printed Paste

Solder Reflow

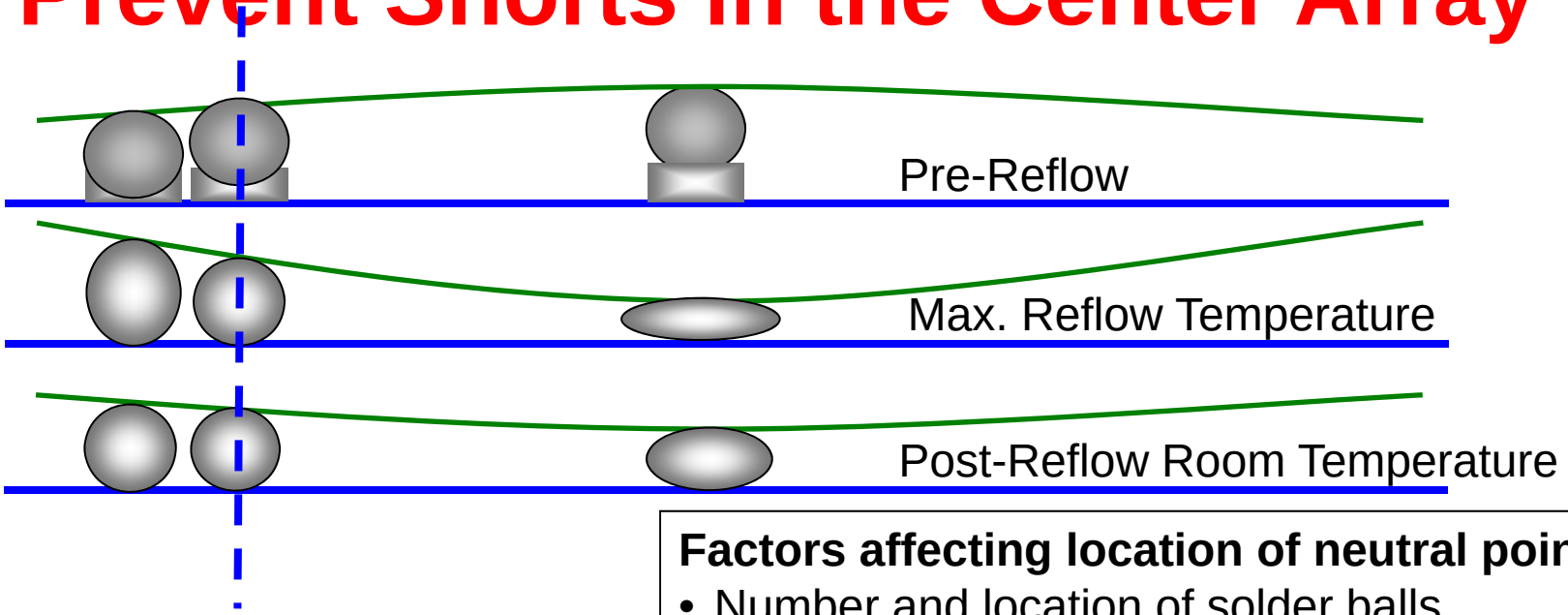




Appendix

- ✓A1: Through molded via solder rework methods
  - Basic repair method
  - Manual rework method
- ✓A2: X-ray examples
- ✓A3: Screen print material and reflow equipment examples
- ✓A4: Package warpage affect examples

Calculating Solder Paste Volume to Prevent Shorts in the Center Array



Neutral solder ball at maximum reflow temperature (nominal height)

Factors affecting location of neutral point:

- Number and location of solder balls
- Solder surface tension
- Pad shape
- Weight of OMAP and Memory packages
- Phone board warpage
- Temperature ramp, uniformity & maximum
- Paste
- Reflow atmosphere

Sketches not to scale

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