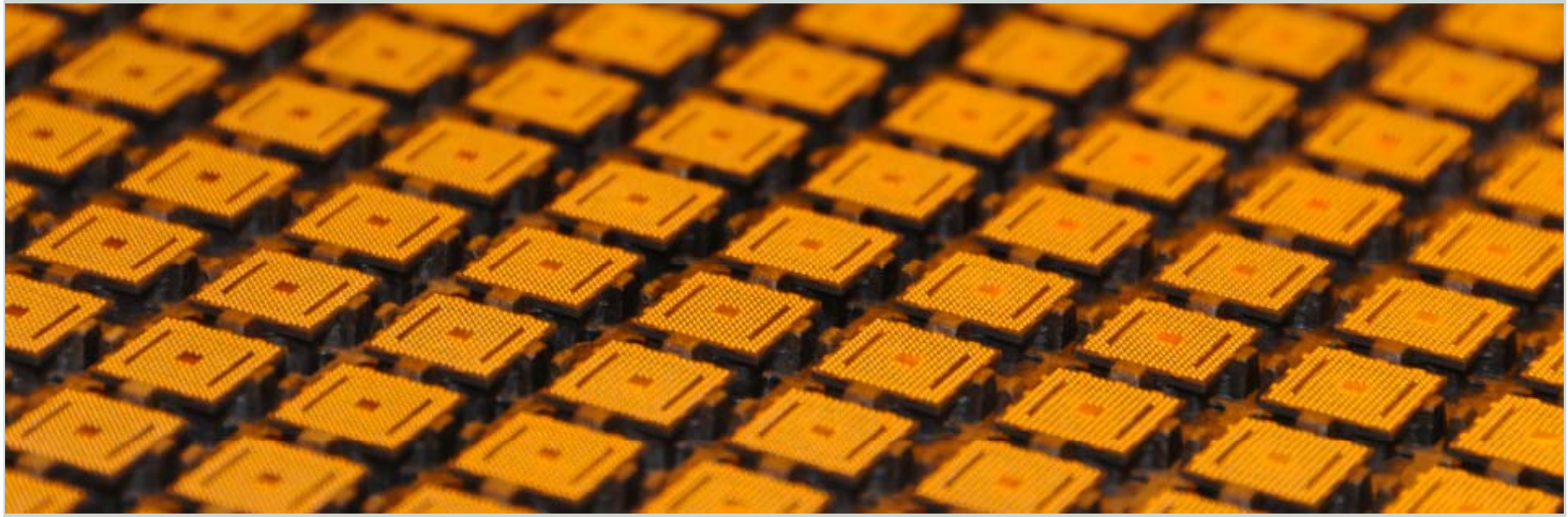

Impact of Process Improvements on Reliability of RCP Technology During Scale-up

Co-authors: George Leal, Dominic Koey, Tony Vessa, Scott Hayes, Tony Gong, Doug Mitchell, Jason Wright, Gao Wei

March 8, 2011

IMAPS Device Packaging Conference

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Freescale's Redistributed Chip Package
IMAPS Device Packaging - 2011

Contents

- RCP Introduction
- Background: 300mm line startup
- Process Down-selection
- Experimental and Reliability Test Plan
- Reliability Results and Analysis
- Conclusions
- Acknowledgements

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Freescale's Redistributed Chip Package - RCP

Cost competitive/area batch process
- No package substrate
- No wire bonds / C4 bumps

High performance package
- reduced electrical parasitics
- higher frequency response

LK/ULK Compatible

Pb-free & Halogen free

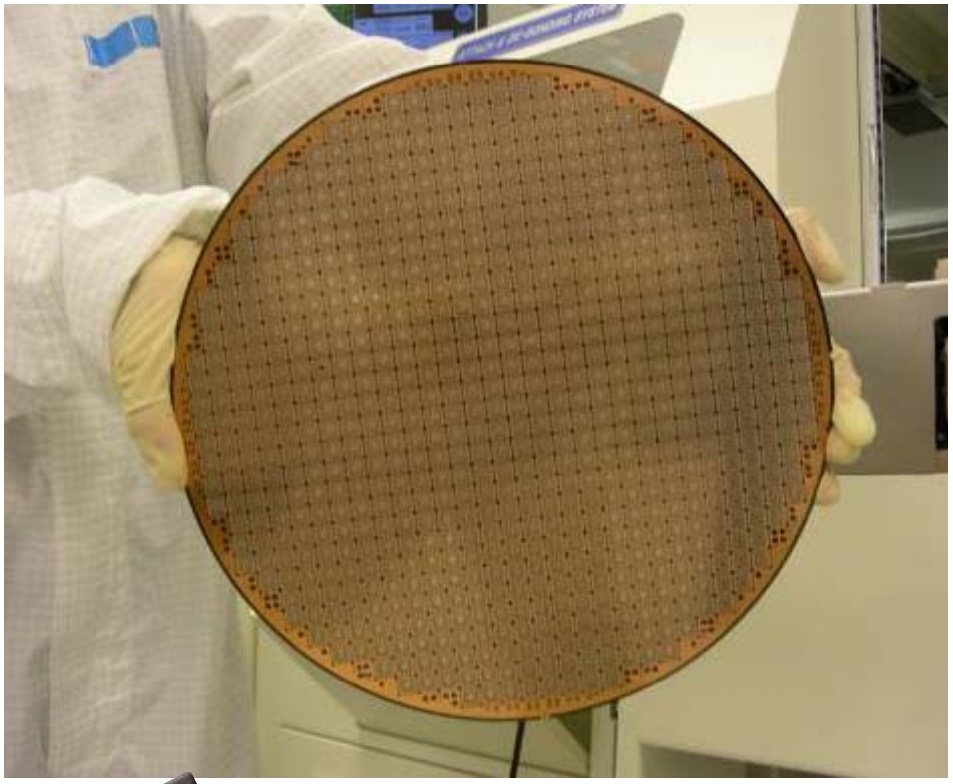
Single/Multi-chip

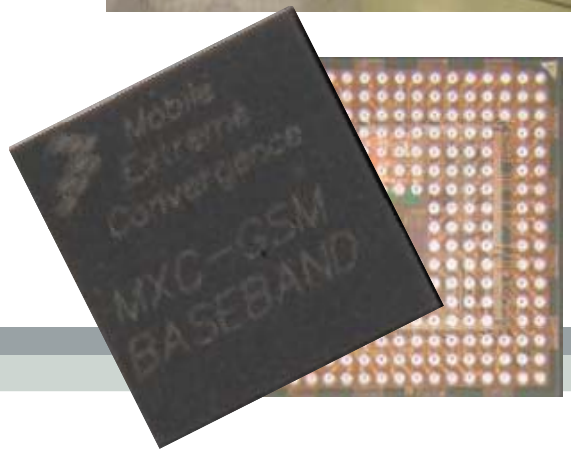
Embedded Components

3-D IC Enabled

Multiple Layers of Redistribution

JEDEC/FSL Commercial
& Industrial Reliability Certified





300 mm round panel
9 x 9 mm packages
258 IO, 0.5 mm pitch
716 packages/panel
2 layer build-up

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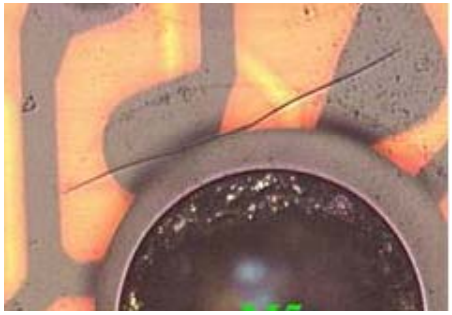
RCP 300mm Line - Background

300mm line – Manufacturing Scale-up

- RCP process developed on 200mm lab tools, manual & semi-manual
- 300mm manufacturing line established with automated production tools
- Could not use “copy exact” strategy
- Attempted to match key parameters at each process step and duplicate process output and reliability performance

Early 300mm line experience



- Testing on early samples showed reliability issues related to dielectric cracking, an issue observed and resolved on 200mm line.
- Cracking was associated with solder mask (SM) adhesion
- Investigations found Cu treatment and solder paste flux had most influence on solder mask adhesion
- Setup experiment to evaluate impact of these 2 variables on reliability

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Initial 300mm vs. 200mm Lab Cu Surface Structure

Initial 300mm

- Spray based process
- Appearance and uniformity dependant on plate rate and environmental factors

200mm Lab

- Immersion process
- Appearance independent on plate rate and environmental factors

Goal: Optimize 300mm to achieve 200mm Cu surface roughness

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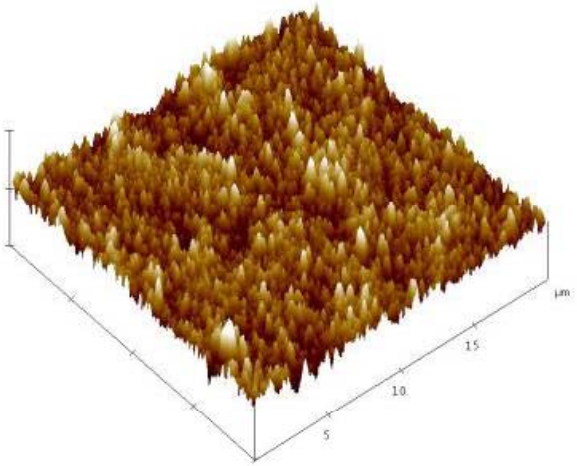
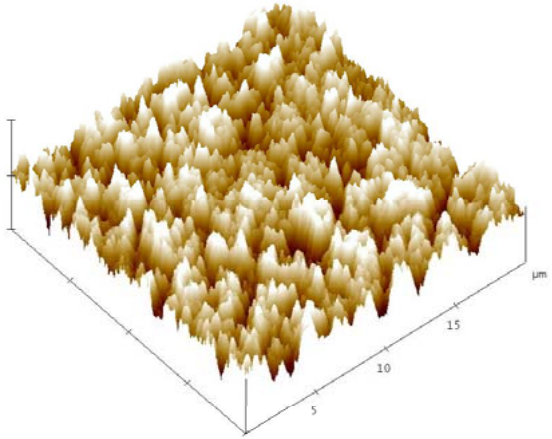
Initial 300mm vs. 200mm Lab Cu Surface Structure

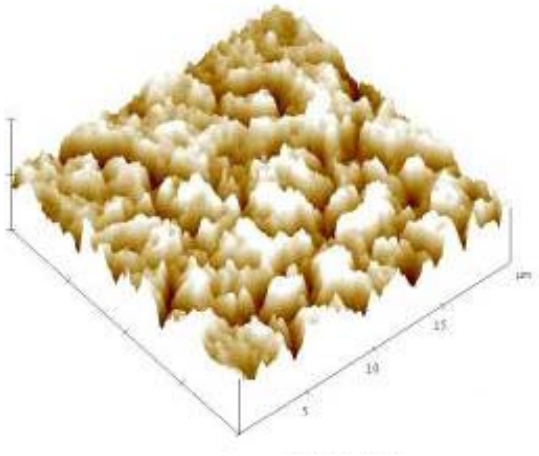
Initial 300mm



200mm Lab-Target



Optimized 300mm



- Targeted roughness was achieved through Cu finishing process optimization

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Solder Flux Selection

Flux Type	Rosin (RO)		Organic (OR)	
Flux Activity Level	Low Activity (L)		Low Activity (L)	High Activity (H)
Halide Content	Halide (H1)	No Halide (H0)	No Halide (H0)	No Halide (H0)
Flux Name	Flux A Baseline	Flux B	Flux C	Flux D
Flux Removal	No Clean	No Clean	No Clean	Water Soluble
SM Delam	39/39	0/39	0/39	0/39

- Flux dispensed on solder pads and reflowed at 260°C
- Pads inspected for SM delamination pre and post reflow
- Halide content was found to be a significant factor causing SM delamination
- Flux D selected due to low post reflow flux residue

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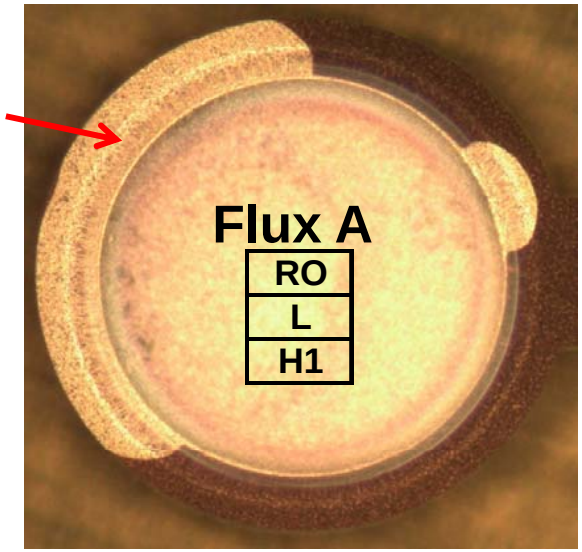
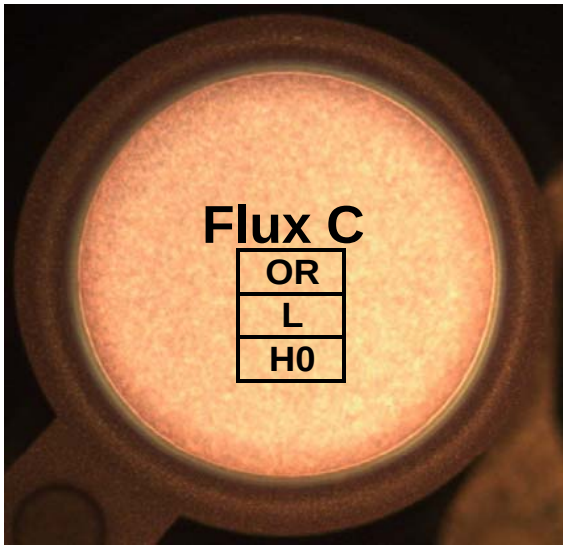
Solder Flux Selection

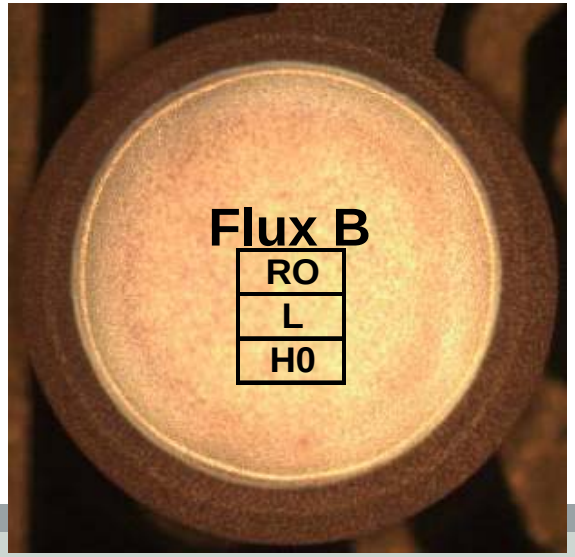
Solder Mask delamination
Shown to result in an eventual electrical failure

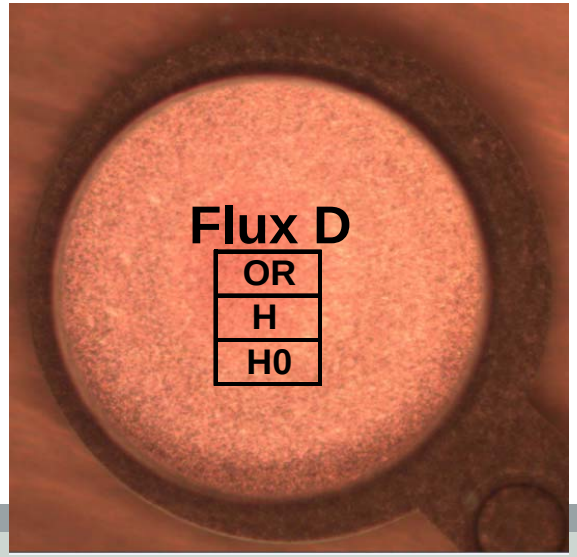




No Delamination

No Delamination





No Delamination

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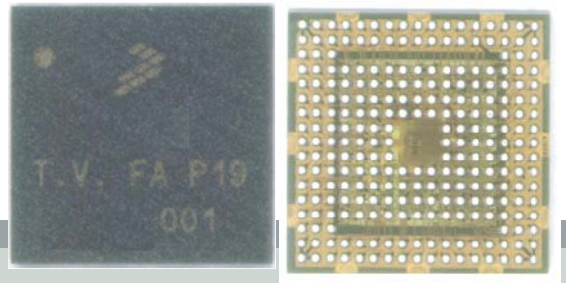
RCP 300mm Line – Experimental Plan

- **Objective:** Evaluate reliability impact of process changes to improve solder mask adhesion
- **Study Factors – see table on next slide**
- **Test Vehicle:**
  - Die: baseband device, 90nm 5LM, 300mm, Al RDL, 5.4x5.8mm, 300um thick
  - Package: 9x9mm, 2 metal layer, 258 I/O, 0.5P, solder bump or BGA
  - Test Platform: ATE with tray to tray type handler, room & hot test capable
- **Build and Reliability Plan**
  - Fabricate one panel of each experimental cell plus 2 control panels
  - Perform e-test at T-zero followed by MSL3 260°C preconditioning
  - Run Air-to-Air Thermal Cycling (AATC) test at -40/125°C & -55/125°C until failure
  - Perform e-test after each readpoint
  - Perform visual inspection at each readpoint

9x9mm RCP Package



Reliability Test Plan

Panel/Cell ID	# Panels	MSL3/ 260C	TC test -40/125C	TC test -55/125C
P1 & P3	2	160	80	80
P11	1	160	80	80
P15	1	160	80	80
P19 & P21	2	160	80	80

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RCP 300mm Line – Experimental Plan

Panel/ Cell ID	Cu Surface Treatment	Solder Paste
P1/P3 (control)	Std 300mm (baseline)	Flux A (baseline)
P11	200mm Lab	Flux D
P15	Std 300mm	Flux D
P19/P21	200mm Lab	Flux A

- 300mm format used for all cells
- 200mm Cu treatment adapted to handle 300mm panels
- Completed RCP panels inspected for SM delamination

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T-Zero Visual Mechanical Inspection Results

Panel/Cell ID	Cu Surface Treatment	Solder Paste	Results (SM Delam %)
P1/P3 (Control)	Std 300mm (Baseline)	Flux A (Baseline)	20%
P11	200mm Lab	Flux D	0%
P15	Std 300mm	Flux D	0%
P19/P21	200mm Lab	Flux A	1%

- 200mm lab Cu surface treatment reduced SM delamination significantly when baseline flux A is used.
- Flux D eliminated solder mask delamination regardless of Cu surface treatment

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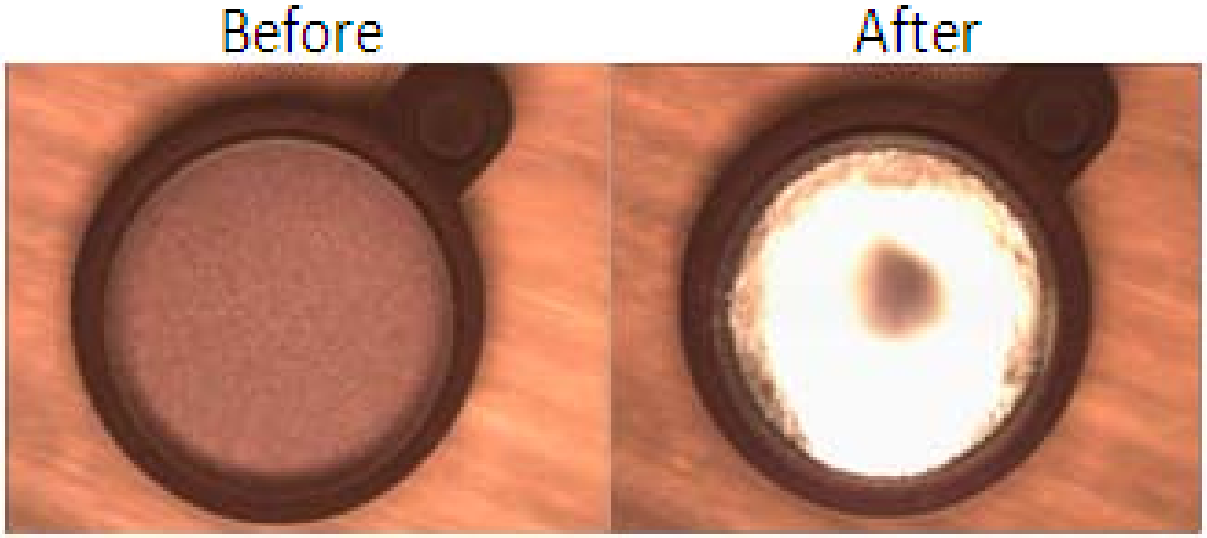
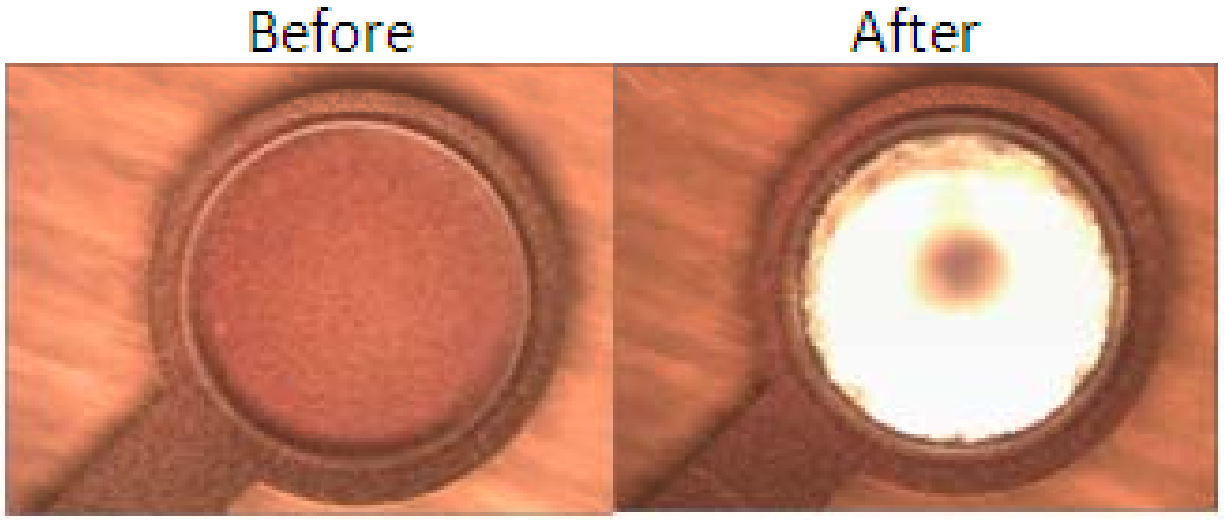
P11 & P15 Post Reflow BGA Pad Condition



Cell P11
200mm Lab/Flux D



Cell P15
Std 300mm/Flux D

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Reliability Test Results

- Visual inspection for dielectric cracks was performed at each readpoint
- Results from visual inspection for -40/125°C condition are shown in table below
- The baseline flow showed issues at 500 cycles, while experimental cells showed much improved resistance to dielectric cracking, especially cell P11.

	Visual Inspection Results,-40/+125°C								
Cell ID	500	850	1000	1500	2000	2500	3000	3500	4000
P1/P3	15/80	27/78	27/73	22/69	28/57				
P11	0/80	0/80	0/80	0/79	0/78	0/76	19/75	53/72	
P11-SM	0/40	0/40	0/40	0/39	1/39	9/38	31/36		
P15	0/80	0/80	0/80	0/79	3/78	13/76	60/74		
P15-SM	0/40	0/40	0/40	6/40	12/38	26/36	33/34		
P19/21	0/80	0/80	0/80	0/79	4/78	10/76	48/74		

Panel/ Cell ID	Cu Surface Treatment	Solder Paste
P1/P3 (control)	Std 300mm (baseline)	Flux A (baseline)
P11	200mm Lab	Flux D
P15	Std 300mm	Flux D
P19/P21	200mm Lab	Flux A

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Reliability Results

- E-test results after assembly yield 95% at room temp, 100% at hot (70°C)
- Time-zero inspection noted SM mis-registration on cells P11 & P15, these cells were split into normal vs misregistered cells (“-SM” label)
- AATC at 2 conditions started after MSL3 @ 260°C preconditioning and e-test
- Table below shows e-test results for -40/125°C condition
- Cell P11 showed best performance, all experimental cells exceeded the control

	E-test Results after TC Test (-40/+125°C)								
Cell ID	500	850	1000	1500	2000	2500	3000	3500	4000
P1/P3	0/80	5/78	3/73	12/69	12/57				
P11	0/80	0/80	0/80	0/79	0/78	0/76	0/75	7/73	9/64
P11-SM	0/40	0/40	0/40	0/40	1/39	0/38	2/36	12/34	
P15	0/80	0/80	0/80	0/79	0/78	0/76	12/74	16/62	
P15-SM	0/40	0/40	0/40	0/40	1/38	1/36	7/34	20/27	
P19/21	0/80	0/80	0/80	0/79	1/78	0/76	8/74	19/66	

Electrical Test Results

Failing units removed from sample before next readpoint

Panel/ Cell ID	Cu Surface Treatment	Solder Paste
P1/P3 (control)	Std 300mm (baseline)	Flux A (baseline)
P11	200mm Lab	Flux D
P15	Std 300mm	Flux D
P19/P21	200mm Lab	Flux A

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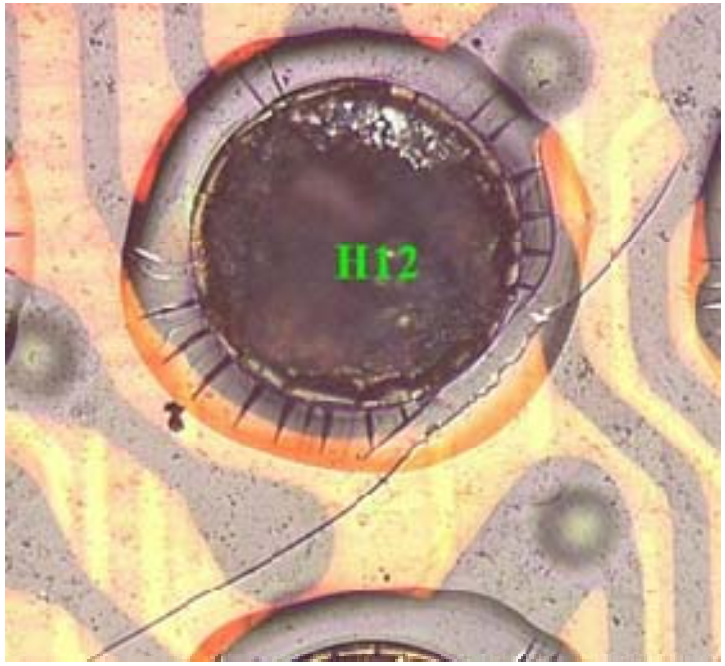
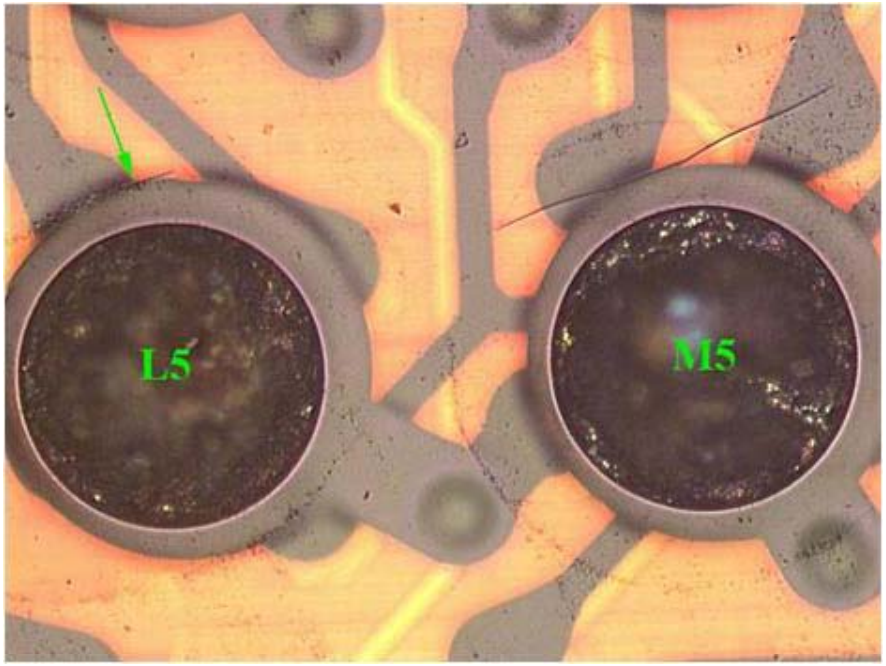
Reliability Test Results

Typical Dielectric Cracking After AATC



Cell P19/21, 1500 cycles -40/125C



Cell P15, 1500 cycles -40/125C

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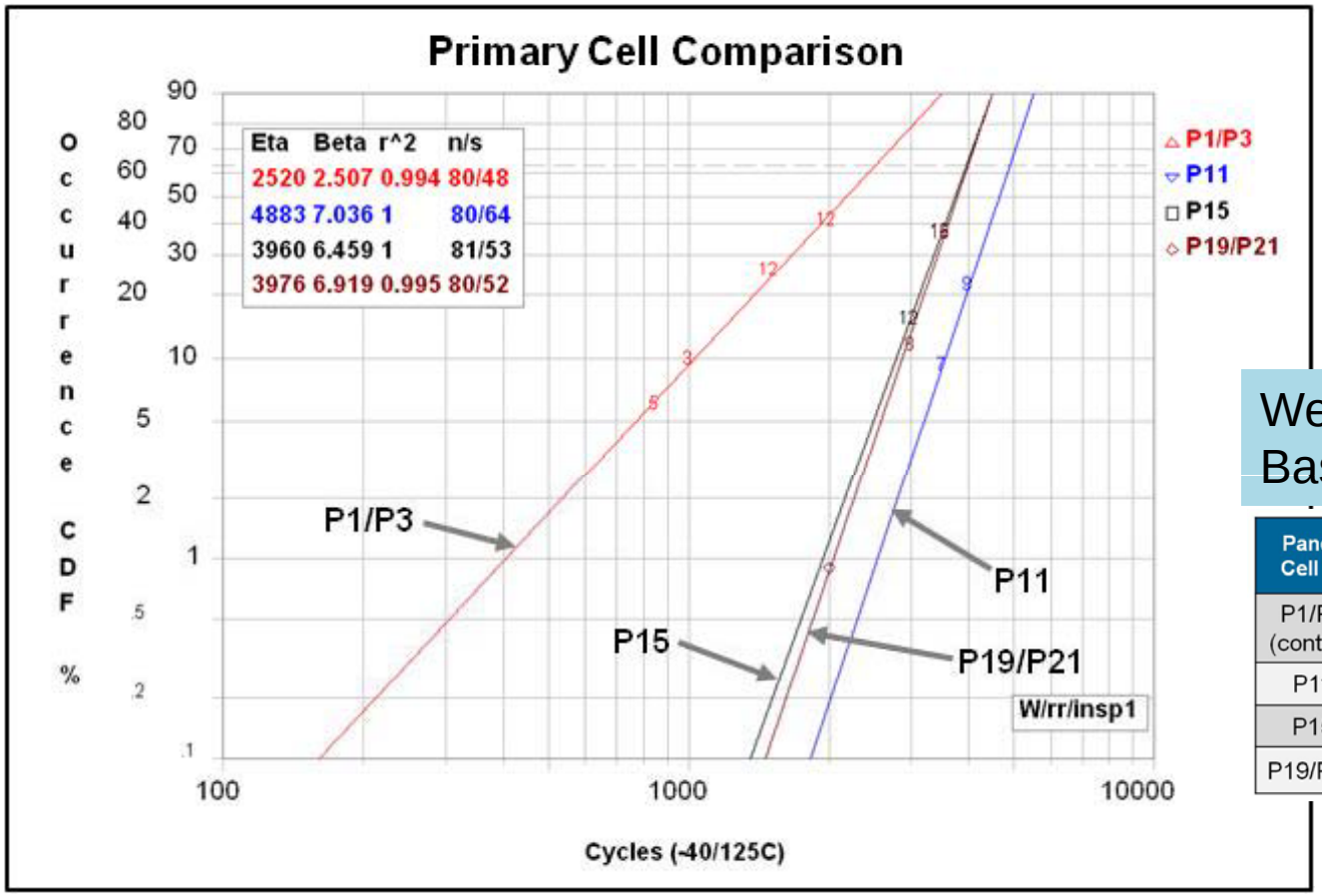
Reliability Results/Analysis



Weibull Plot: Reliability Based on E-test Results

Panel/ Cell ID	Cu Surface Treatment	Solder Paste
P1/P3 (control)	Std 300mm (baseline)	Flux A (baseline)
P11	200mm Lab	Flux D
P15	Std 300mm	Flux D
P19/P21	200mm Lab	Flux A

- Weibull plot shows clear life improvement of experimental cells vs the control
- Characteristic life of cell P11 is approximately 4800 cycles
- 200mm treatment and Flux D provide similar level of improvement

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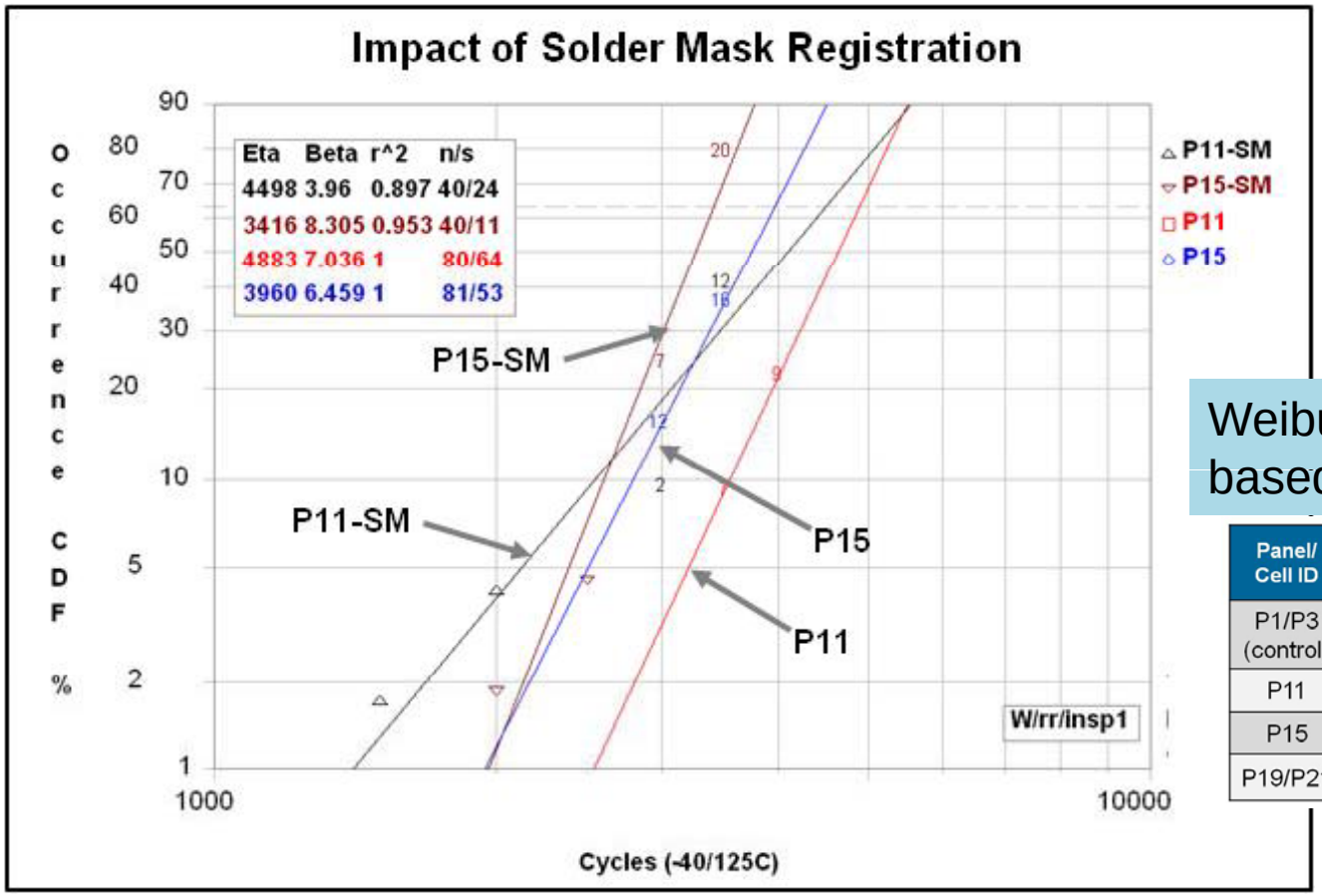
Reliability Results/Analysis



Weibull Plot: Reliability based on SM Registration

Panel/ Cell ID	Cu Surface Treatment	Solder Paste
P1/P3 (control)	Std 300mm (baseline)	Flux A (baseline)
P11	200mm Lab	Flux D
P15	Std 300mm	Flux D
P19/P21	200mm Lab	Flux A

- Weibull plot shows misregistered SM has small impact on reliability
- The SM misregistration would be a concern only for high reliability applications

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Conclusions

- Study revealed both experimental factors were influential in reducing solder mask delamination, cracking and electrical failures.
- The reliability improvement was additive, with combined impact of both factors yielding 3000 cycles lifetime before first e-test fail.
- Solder mask registration appeared to have a small but detectable affect on reliability.
- Characteristic life of multi-layer RCP was shown to be in excess of 4000 cycles for -40/125°C.

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Revised 300mm Optimization & Cu Surface Structure

Critical Factors	Changes from Initial 300mm
Plating Rate	60% increase
Etchant Temperature	10°C increase
Etchant Concentration	Double

- Revised 300mm process RMS value matched 200mm lab process
- Cu surface structure is less dense and nearest to 200mm lab structure

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