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Qualification of ALIVH-G Boards for Handset Assembly

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Abstract
The trends of increased functionality and reduced size of portable wireless products, such as handsets; PDAs are demanding increased routing densities for printed circuit boards. The handheld wireless product market place demands products that are small, thin, low-cost and lightweight and improved user interfaces. In addition, the convergence of handheld wireless phones with palmtop computers and Internet appliances is accelerating the need for functional circuits designed with smallest, low-cost technology.

Historically, the industry has met this challenge through high density interconnect technology and increased silicon integration and component miniaturization. Microvia high density interconnect (HDI) also known as build up technology, is one method for constructing circuit boards with high routing density demands.[1]

For HDI board, vias can be formed using unreinforced dielectric such as Resin Coated Foil (RCF), using processing techniques such as laser drilling or photoimaging. The vias are then metallized using electroless copper/electrolytic plating. The advantage of the HDI construction is the ability to create smaller vias (6 mils) and via pad sizes. This enables higher routing density, lower metal count, reduced board area and increased functionality as compared to conventional boards. HDI improves the wiring density by using build up microvias in the outer layers. However there is still dead space where components cannot be mounted and lines cannot be wired, because of staggered via hole structure.

On the other hand, ALIVH-G (Any Layer Interstitial via Hole) needs no through hole. This is because any two layers are electrically connected by IVH (Interstitial via Hole). The IVH can be placed in any position. Since there is no through hole that disturbs interconnections between components, the dead space becomes reduced and the wiring capability is improved greatly.[2]

Past board technologies used stacked microvias on the outer layers. Current board designs use ALIVH-G technology. These vias are laser drilled and the interconnection technology used is conductive copper paste. The typical design rule is Lines/Space 100/100 micron and Via /Land is 200/400 microns. ALIVH-G technology makes a lightweight substrate (less than 100g)

The paper presents the evaluation conducted to ensure the stability of the laminate and microvias through the double sided reflow process. This was evaluated as a part of the phone product qualification build.

Introduction
Higher density packages and PWB applications requirements are driving the need for high-density interconnect design capabilities using microvias. The benefit of using ALIVH-G is the ability to incorporate high density, high performance area array packages to increase performance of handsets, PDAs etc. Microvias are typically formed on an epoxy resin laminate or dielectric layers of the PWB. (Figures 1 and 2)

ALIVH-G technology is emerging in the handset industry; however, production level reliability data for double-sided surface mount assembly is not readily available. This requires users to establish their own reliability data.

This paper presents the assembly qualification of the ALIVH technology thru 2 pass reflow and rework. Results of solder joint reliability testing, shear test and X-sectional analysis are presented.

PWB Design and Fabrication
The PWB was designed as an 8 layer thin board 0.8 mm thick. The PWB had an ALIVH -G configuration with copper paste microvias in all layers. ALIVH-G type substrate uses epoxy glass instead of Aramid paper, which has higher moisture absorption. This eliminates baking of the PWB prior to refold. Table 1 compares the properties of ALIVH–G type substrate with conventional ALIVH and FR-4 substrate.[2]

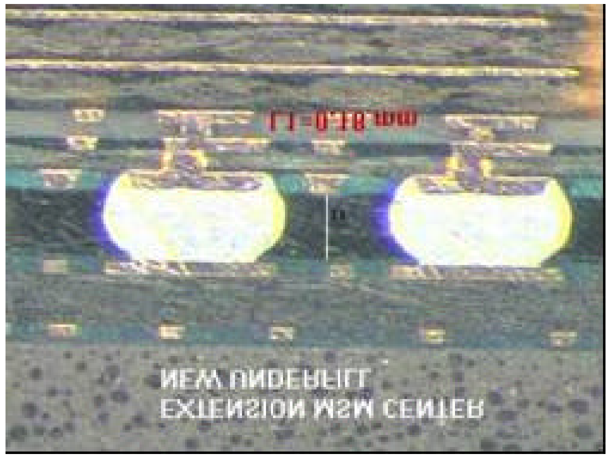

Figure 1 - HDI PWB

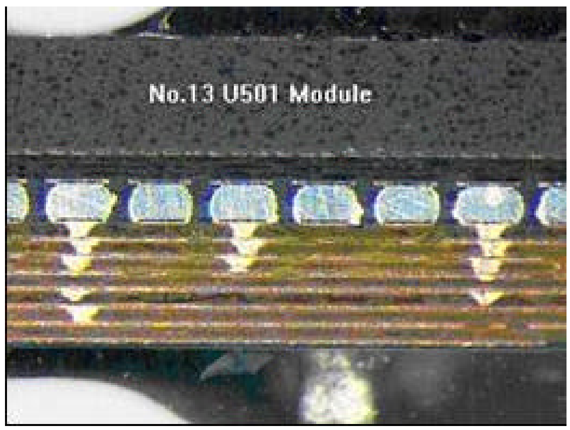

Figure 2 - ALIVH PWB

Table 1 - Properties of ALIVH-G type, Conventional ALIVH and FR-4 Substrate

Properties	ALIVH-G Type	Conventional ALIVH	FR-4
Water Absorption (wt%)	0.5	2.1	0.8
Tg (degrees C)	170	170	125
CTE (PPM/degrees C)	11	11	16
Flexural Modulus (Gpa)	30	13	21
Hardness (Gpa)	2.6	2.6	0.6
Density (g/cc)	1.9	1.4	1.9

Board Assembly

Board assembly process was a double sided surface mount assembly soldering of ball grid array packages, connectors, chip resistors, capacitors, and diodes.etc. The assembly was reflowed in convection air at a peak temperature of 219C. The solder paste used for assembly was tin/lead 2% silver (62/36/2) – no clean version.

Mask defined as well as Etch defined pads were used for soldering BGAs. (Figures 3 and 4) This evaluation was necessary as historically KWC has used etch defined pads, while mask defined pads are commonly used in ALIVH technology. Shear testing was conducted to compare the differences. Shear values were also compared to existing etch defined pads used in HDI boards. Ball shear was also conducted by soldering 0.3 mm and 0.4 mm solder balls on the pads. No microvia damage was seen after shear, but etch defined pads showed lifted pads. Figure 3 and 4 show a comparison of etch Vs mask defined pads. Table 2 shows the shear values.

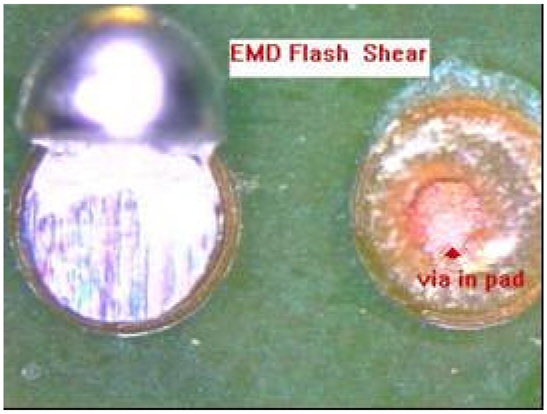

Figure 3 - Etch Defined Pad

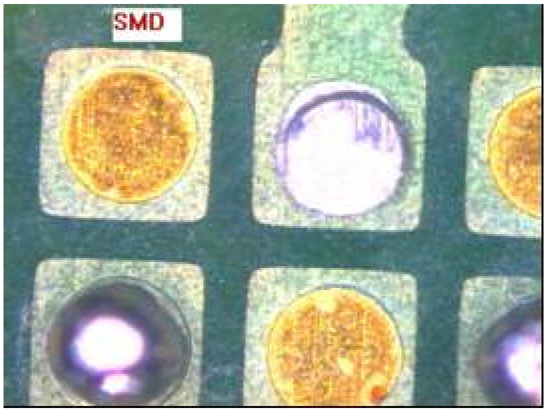

Figure 4 - Mask Defined Pad

Table 2 - Shear Test Post Reflow (Pounds)

	EMD # 1	EMD # 2	SMD # 1	SMD # 2
MSM	39.55	40.55	45.55	53.10
FLASH	22.25	25.20	47.60	31.20
U300	22.50	26.50	28.35	23.40
U101	35.05	34.10	38.85	23.35
U151	27.20	24.30	24.60	22.55
YJ4802(BATT)	34.10	39.75	44.15	36.41
QN601(CONN)	38.50	39.90	41.05	36.35
402 #1	2.35	2.40	1.60	2.80
402 #2	2.40	3.65	3.35	2.75
402 #3	2.15	2.65	2.50	2.00
402 #4	3.50	1.95	2.20	1.90

Post Reflow X-Sections

X-sections were performed on the BGA packages and other components to evaluate the quality of the solder joints and ensure compliance to IPC 610 – Rev C for leaded packages and IPC 7095 for BGA packages. Also microvia integrity was evaluated with X-sectional analysis. X-sections showed acceptable solder joints and no degradation of microvias.[3, 4] Figure 5 shows the X-sections on an etch defined pad and Figure 6 shows the X- section of a mask defined pad. The standoff height of the joint is higher for a mask-defined pad. For PWB assembly process, lot/lot consistency is essential. The tolerances of the etching process are preferred as compared to the solder mask apply process. However, due to shear values being higher for mask defined pads, a decision was made to go with mask defined pads for BGA packages.

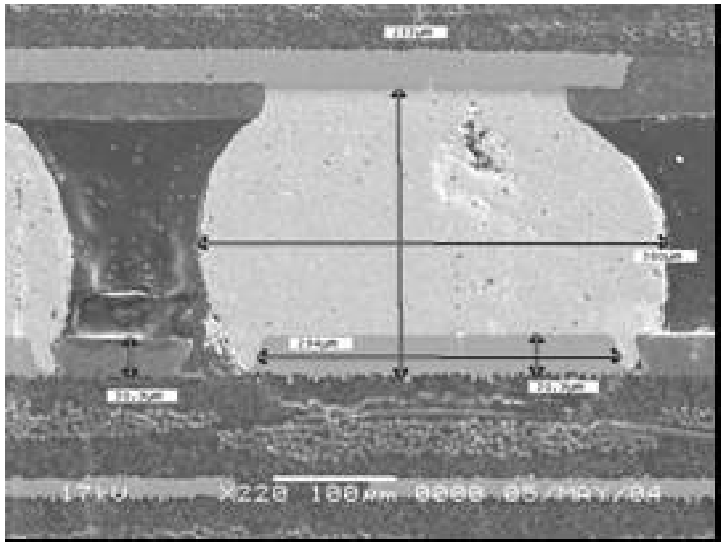

Figure 5 - BGA Solder Joint - Etch Defined Pads

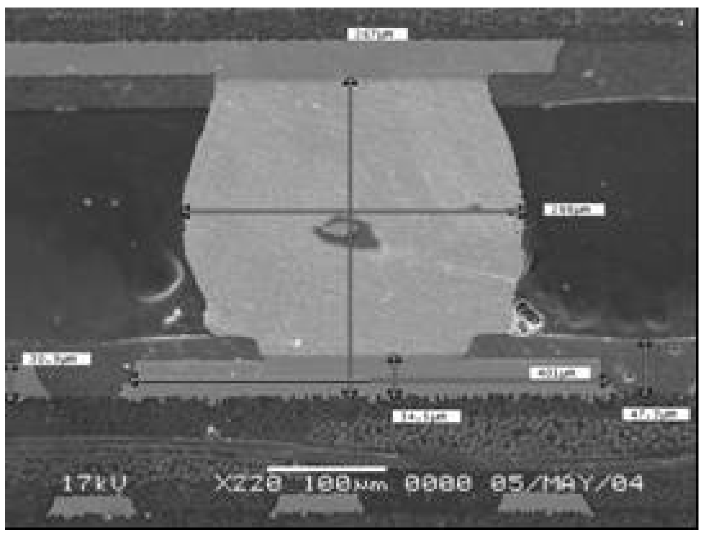

Figure 6 – BGA Solder Joint – Mask Defined Pads

Rework Evaluation
Rework of SMT packages is performed using hot air soldering tools and application heat using controlled ramp/soak profile. The concern was damage to microvia connections and PWBs pads during component removal and reattach. Component rework was performed 2X on the leaded packages and 1X on the Ball-Grid Array packages. All packages survived rework. There was no damage to PWB pads, or blistering of solder mask during rework. No damage was seen on microvia connections. Figure 7 and Figure 8 show PCB surface after package removal showing no lifted pads.

Solder Joint Reliability Test
Solder joint reliability testing was performed for assembly qualification per IPC SM 785. Assemblies were thermal shock tested from –25C to +125 for 500 cycles.[4] Temperature humidity testing was performed at 85C/85% Relative Humidity for 1000 hours. Samples were X-sectioned post-test to evaluate the joint quality. The joints appeared slightly grainy after thermal shock test and oxidized after temp.humidity testing, but no cracks were seen in the joints. No separation was seen where the microvia connected to the capture pad. Figure 9 and 10 show X-sections after temp.humidity test. Figure 11 and 12 show X-sections after thermal shock. No cracks on solder joints or separation of vias were observed.

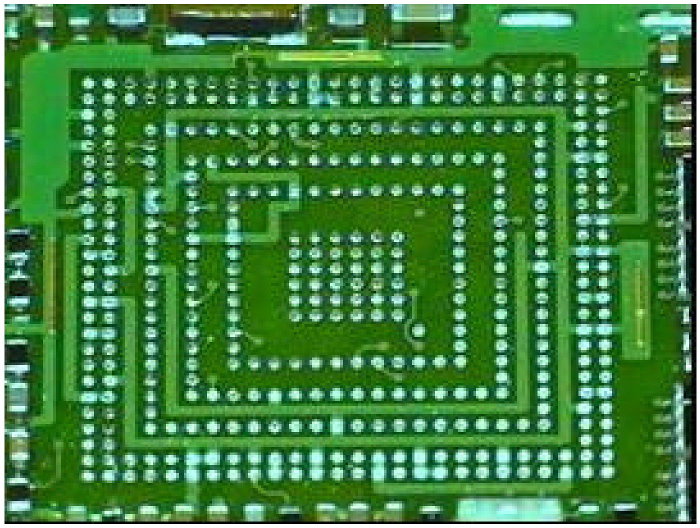

Figure 7 - BGA Pads 0.3 mm after Package Removal

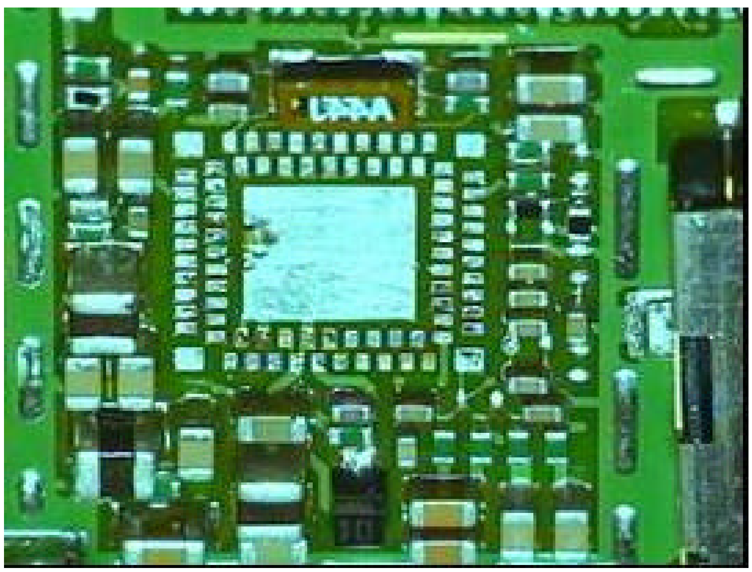

Figure 8 - BCC Pads after Package Removal

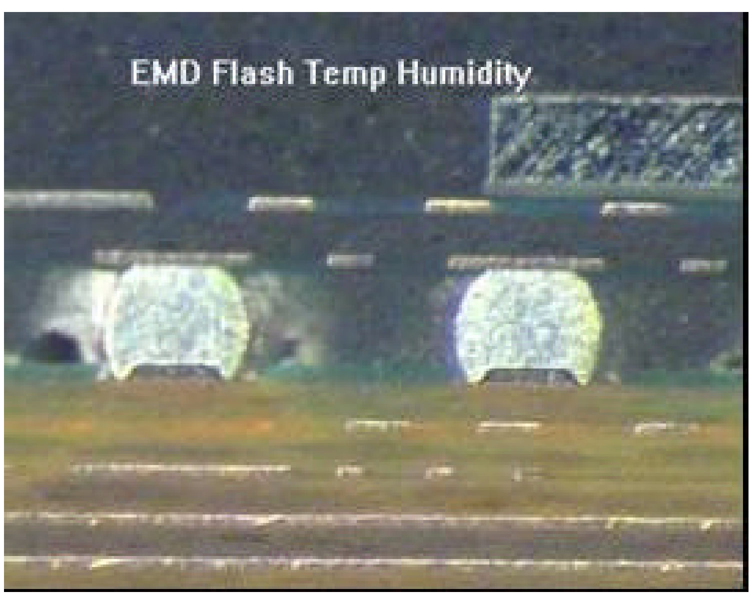

Figure 9 – X-sections Post Temp. Humidity

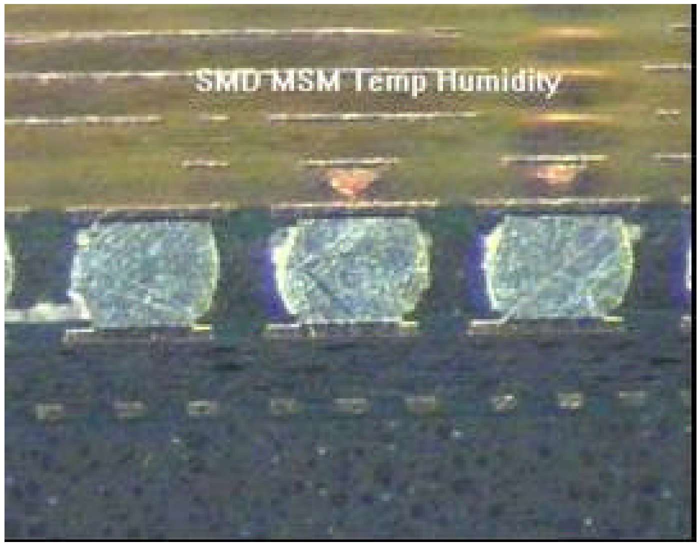

Figure 10 – X-section Post Temp. Humidity

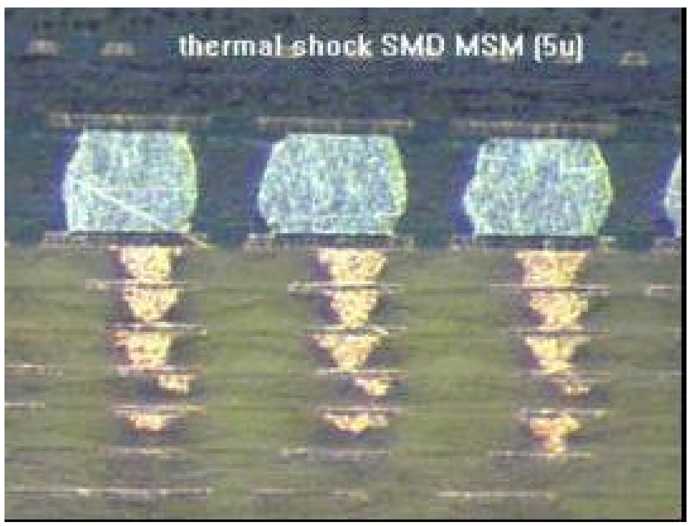

Figure 11 - X-sections Post Thermal Shock

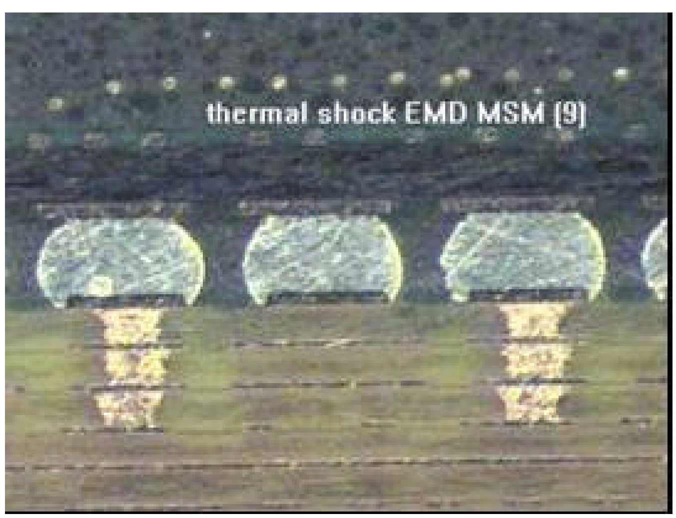

Figure 12 - X-sections – Post Thermal Shock

Phone Level Drop Test

Phone level drop tests were performed at 1.5 meters on a hard vinyl surface. Assemblies were X-sectioned post drops to evaluate solder joints and microvia connections. No solder joint failures or microvia cracks were seen after drop test. However, some pads ruptured from the PWB. This is contributed by the lower bond strength of copper to the ALIVH laminate.

Conclusion

Stacked microvias ALIVH PWBs have demonstrated reliability thru 2X reflow and rework operations. The assemblies have survived thermal shock and temperature and humidity and drop shock testing. Since, no failures or cracks were seen in the joints or microvias, the assembly passed solder joint reliability qualification testing. In order to better understand the ruptured pads after drop, dynamic high g shock testing will be conducted to understand the limits of the PWB to copper adhesion.

References

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2. The Progress of the ALIVH Substrate- Daizo A., Yoshihiro T., Tadashi N., Fumio E.
3. IPC A-610 Rev C – Acceptability of Electronic Assemblies
4. IPC 7095- Design and Assembly Process Implementation for BGAs
5. IPC SM 785 – Guidelines for Accelerated Reliability Testing of Surface Mount Solder Attachments

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ALIVH™ Technology Evaluation for Handset Assembly

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Properties of ALIVH-G, ALIVH and FR-4

Properties	ALIVH-G Type	Conventional ALIVH	FR-4
Water Absorption(wt%)	0.5	2.1	0.8
Tg(degrees C)	170	170	125
CTE(PPM/degrees C)	11	11	16
Flexural Modulus(Gpa)	30	13	21
Hardness(Gpa)	2.6	2.6	0.6
Density (g/cc)	1.9	1.4	1.9

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ALIVH/HDI Technology Comparison

- **ALIVH-G**
- Microvia pad Size 0.3 mm
- Microvia Drill Size -0.13mm
- Trace Width - 0.1mm
- All Layer Microvias
- Copper Paste Vias
- Solder Mask Opening .050mm
- Glass Transition -175C

- **HDI**
- Microvia Pad size 0.25mm
- Microvia Drill Size -0.10mm
- Trace Width - 0.1 mm
- Outer 2 layers
- Electroplated Vias
- Solder Mask Opening .075 mm
- Glass Transition - 140C

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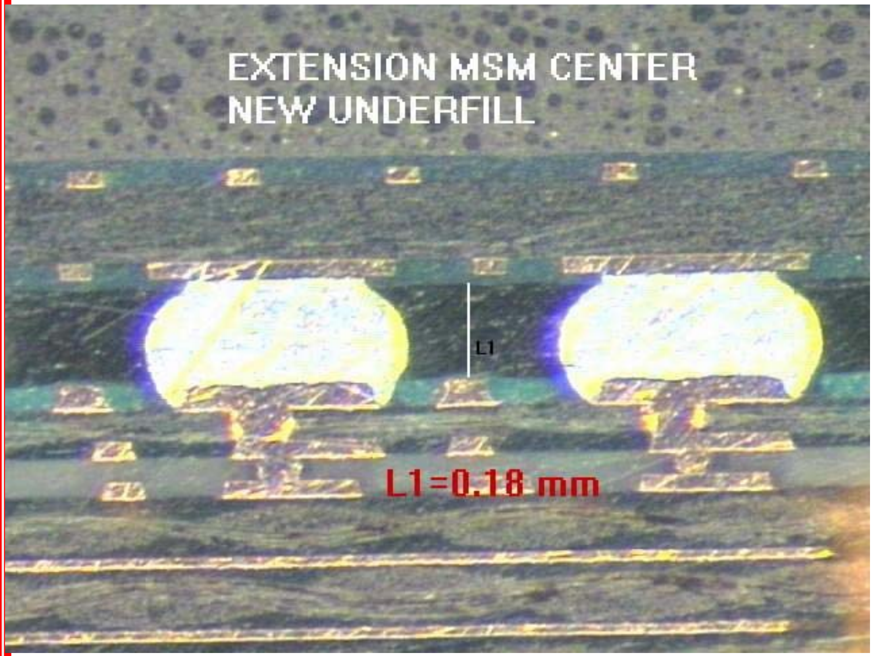
ALIVH/HDI PWB X-section

HDI PWB



ALIVH PWB

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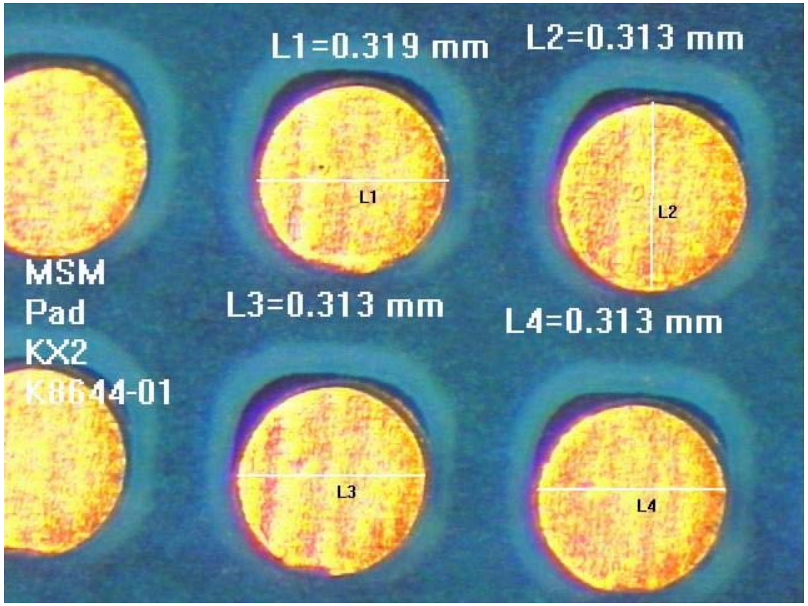
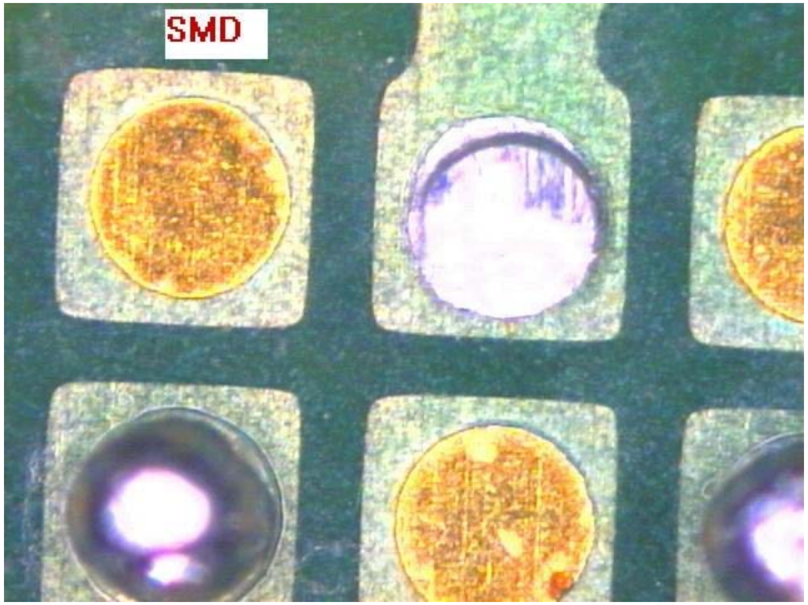
Etch vs Mask Defined Pads

Etch Defined Pads



Mask Defined Pads



Reflow Process

- Double Sided Reflow
- Convection Air
- Peak Temp. - 219C
- Solder Paste - Tin/Lead /Silver (62/36/2)
- No Clean Flux

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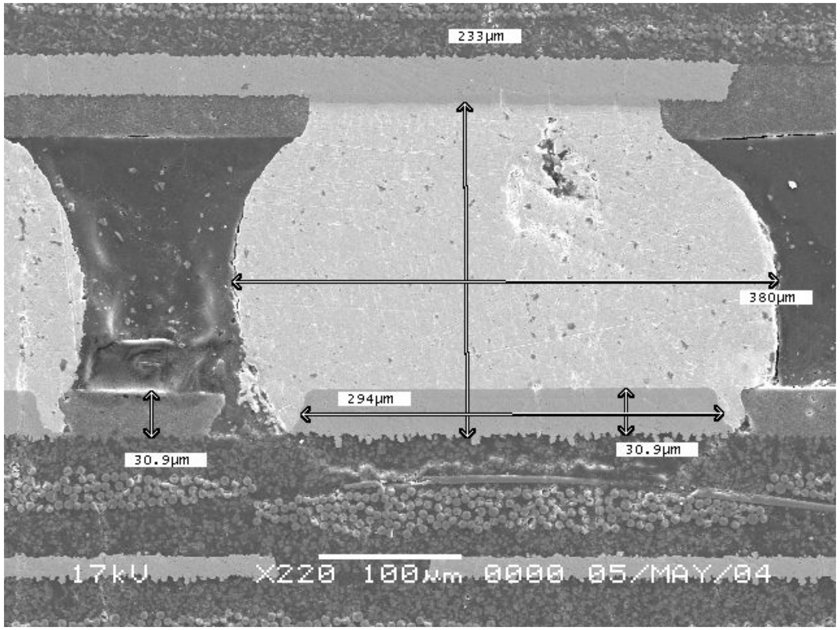
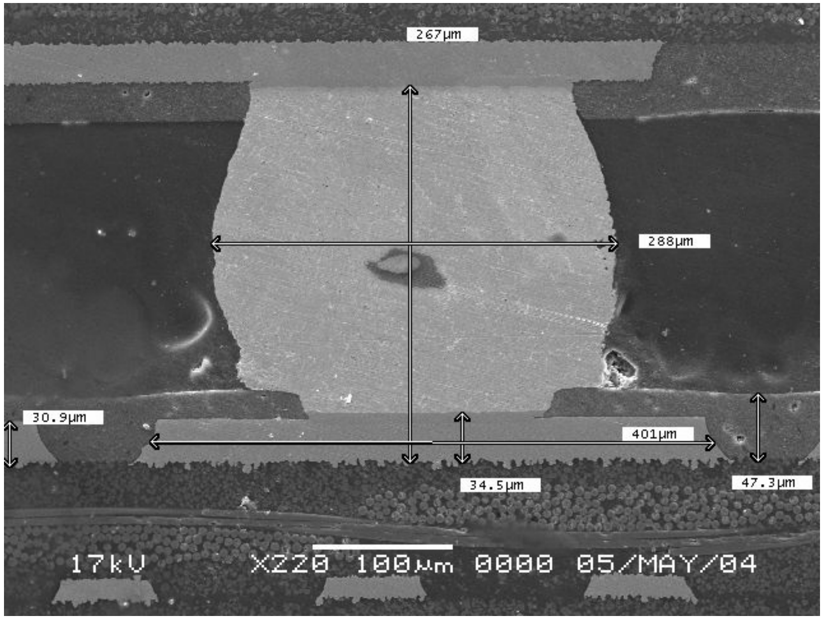
Solder Joints- Etch/Mask Defined Pad

Etch Defined



Mask Defined



Shear Test - Post Reflow

- BGA/SMT Packages Sheared
- Etch Defined/Mask Defined Pads
- Comparison with HDI Boards
- Ball Shear
- Results
  - Mask Defined Pads have Higher Shear Values
  - ALIVH Shear Values are lower than HDI for Etch Defined

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HDI PWB Shear Test- Etch Defined

Shear Test - HDI PWB Units Pound		
Package	Avg.	Std . Devn
U45(FLASH)	49.87	10.06
U32(MSM)	89.00	15.85
J24(CONN)	20.75	1.00
U42(PM6000)	44.07	4.18
U43(RFR6000)	43.85	1.42
U44(RFT6100)	54.20	12.63
FL18(ESD FILTER)	4.32	0.93
J23(CONN)	55.50	4.65
J21(BATTERY)	37.89	2.59
J12(SUPERJACK)	27.39	4.85
S17(SWITCH)	5.45	1.46

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Etch/Mask Defined Shear Test

Pound Force	Avg. Shear EMD	Std. Devn.	Avg. Shear SMD	Std. Devn
MSM	40.05	0.71	49.33	5.34
FLASH	23.73	2.09	39.40	11.60
U300	24.50	2.83	25.88	3.50
U101	34.58	0.67	31.10	10.96
U151	25.75	2.05	23.58	1.45
YJ4802(BATT)	36.93	4.00	40.28	5.47
QN601(CONN)	39.20	0.99	38.70	3.32
402 #1	2.38	0.04	2.20	0.85
402 #2	3.03	0.88	3.05	0.42
402 #3	2.40	0.35	2.25	0.35
402 #4	2.73	1.10	2.05	0.21

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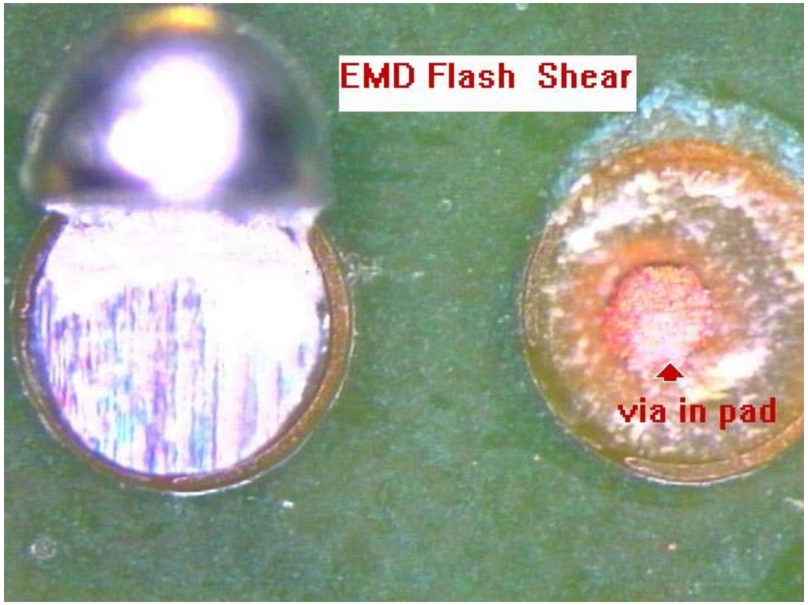
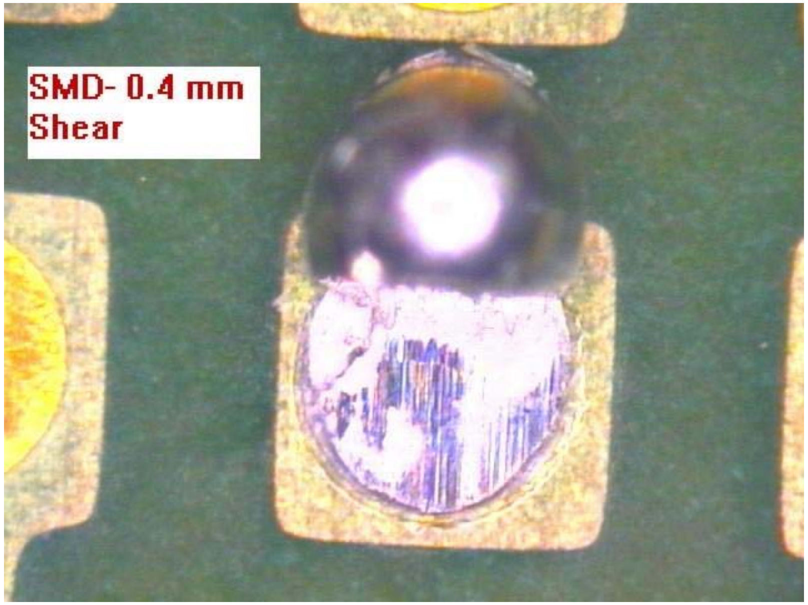
Shear Test- Etch / Mask Defined

Pad Lift - Etch

Shear - Mask Defined



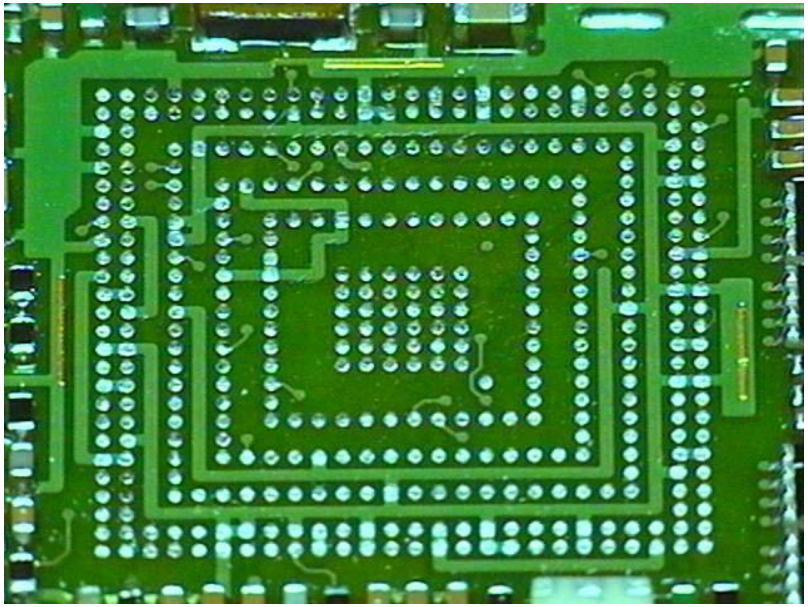


Rework Process Evaluation

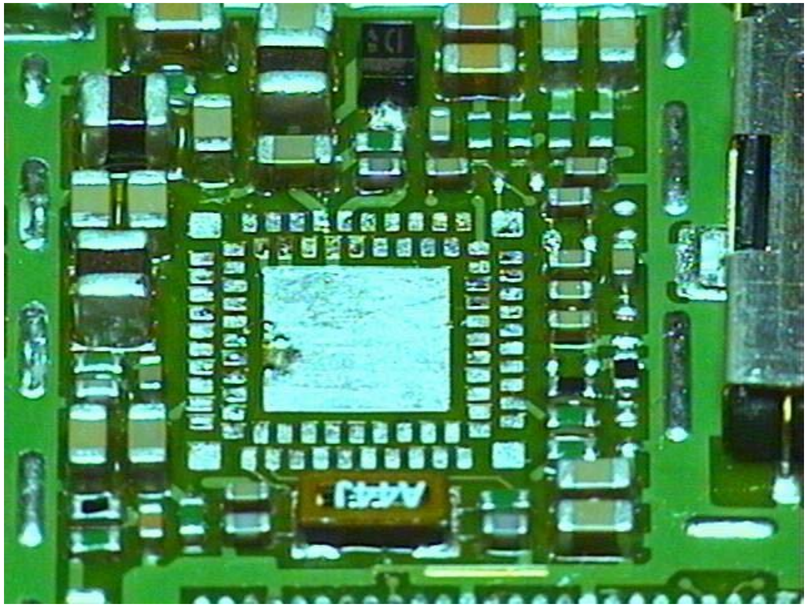
- Component Removal and Replacement
- Hot Air Tool
- BGA Packages - 1X rework
- SMT Packages - 2X Rework
- Results:
  - Microvia Connections Intact
  - Minimal Lifted Pads During Package Removal
  - No Solder Mask Blisters
  - Did not require PWB pre-bake

PWB Surface After Component Removal

BGA Pads



BCC Pads



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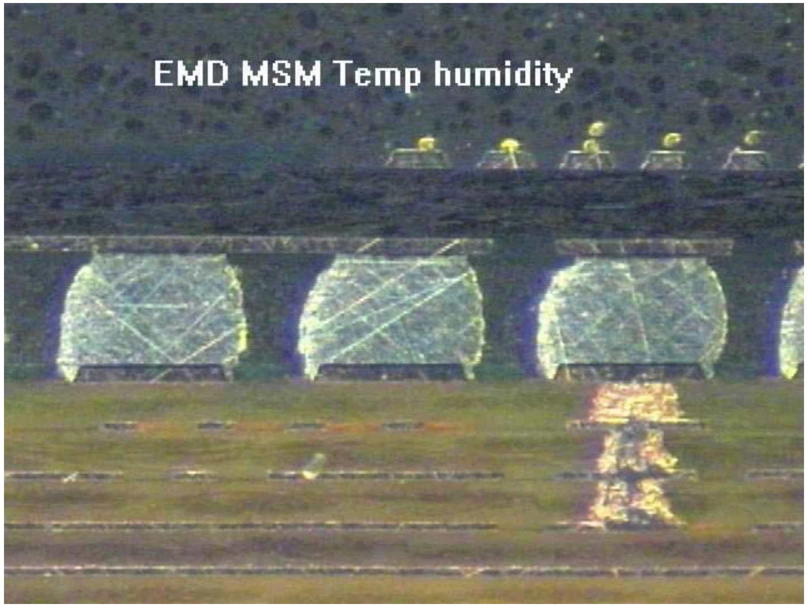
Solder Joint Reliability Test

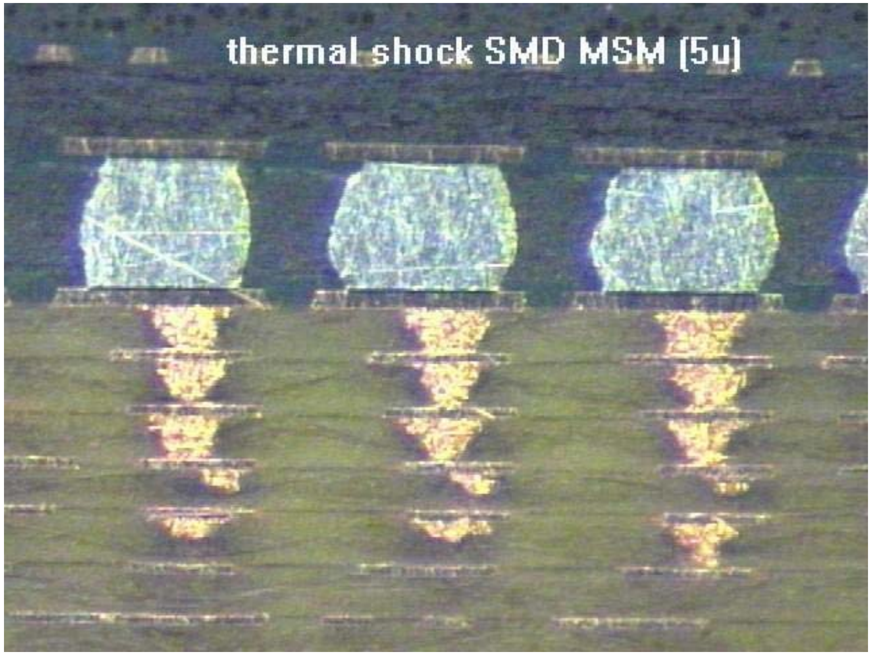
- Reliability Testing per IPC SM 785 and IPC-9701
- Temp. Humidity Test - 85C/85%RH 1000 hours
- Thermal Shock Test -25C to + 125C - 500 Cycles
- Post Test And X-sectional Analysis
- Results
  - Solder Joints Acceptable per IPC 610 - Rev C
  - No cracks, voids or cold solder
  - No separation or degradation of microvia connections
  - Mask/Etch defined pads passed reliability test
  - Ceramic Package cracks due to CTE mismatch

X-Section- Post Temp. Humidity

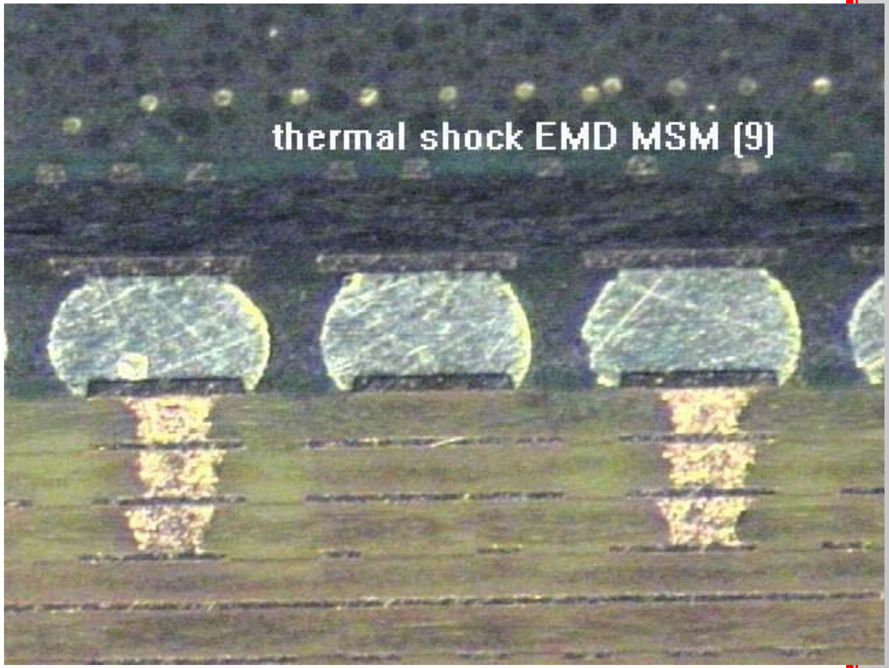


X-sections - Post Thermal Shock

Mask Defined Pads



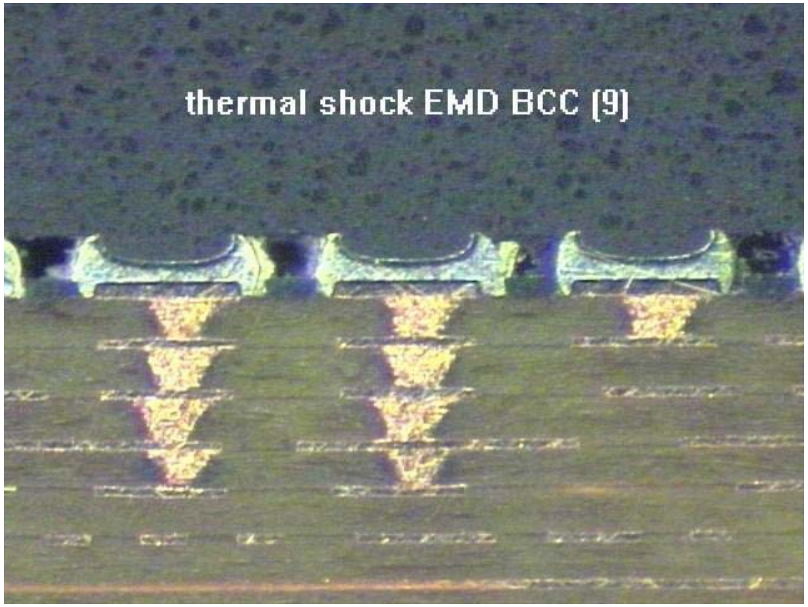
Etch Defined Pads

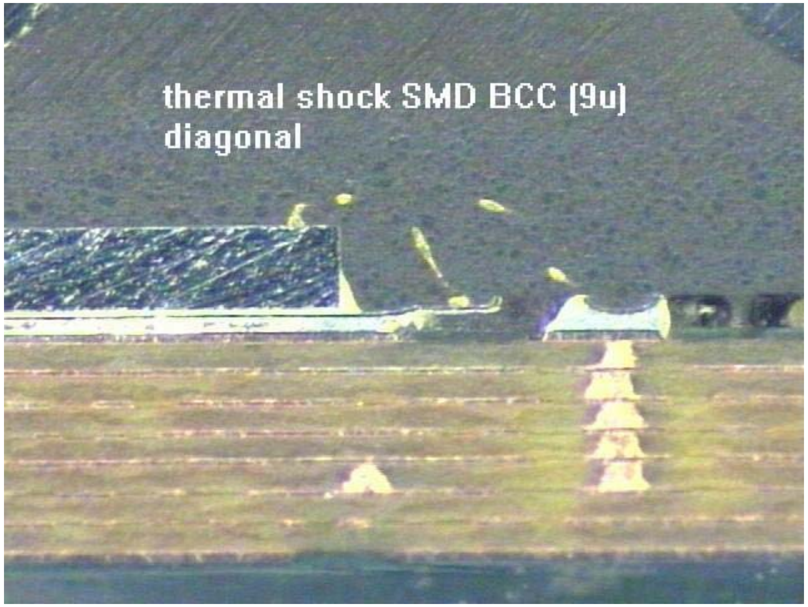


X-Section - Post Thermal Shock- BCC

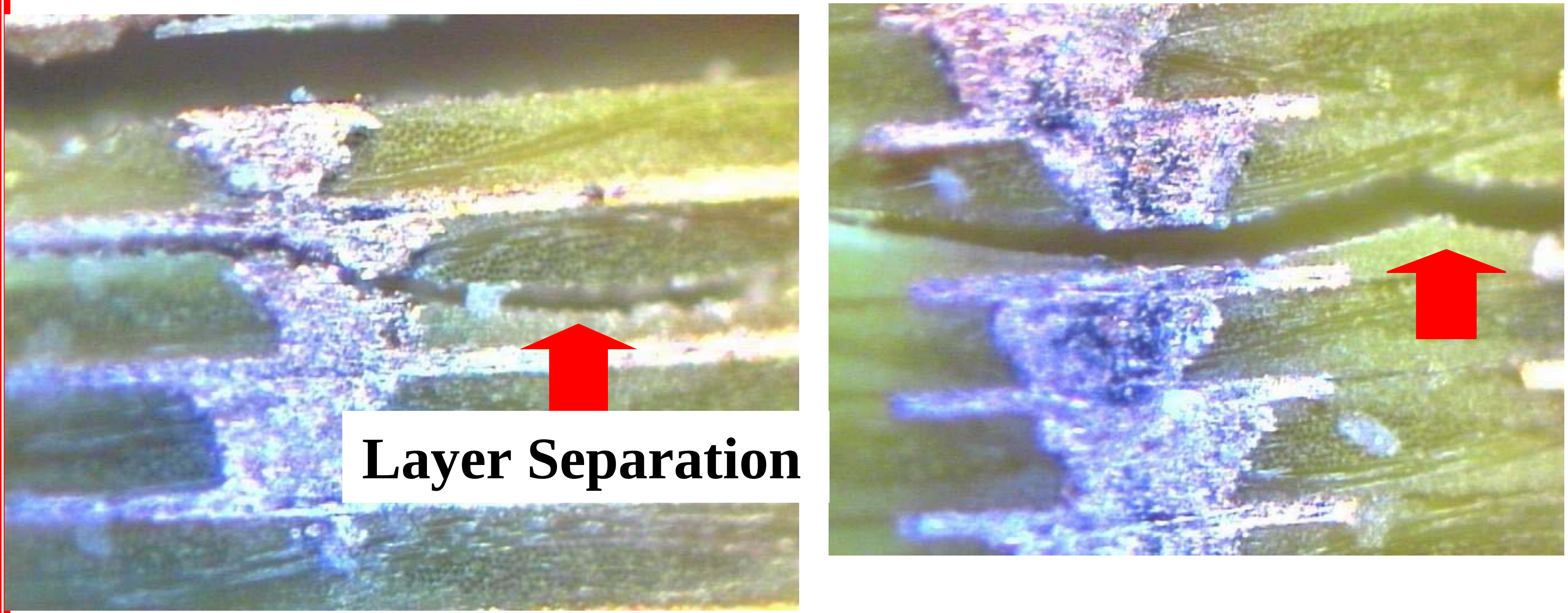
Etch Defined Pads

Mask Defined Pads





Mechanical Integrity



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Conclusions

- Thermal Stability - Acceptable
- Solder Joint Reliability- Meets IPC Spec.
- Mechanical Integrity - Acceptable Static Testing
- Drop Test - No Solder Joint Cracks
- Handling Damage Assessment(Minimal Lifted Pads)
- ALIVH Technology Acceptable for Handset Assembly

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Future Outlook

- High G Shock Evaluations
- Mechanical Integrity of Halogen Free Laminate
- Compatibility of Underfill Application Process
- Evaluate Lead Free Reflow Process

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Lead Free BGA Solderability Qualification

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Agenda

- Package /PWB Description
- Assembly Process
- Misalignment Experiment
- X-Sections
- Reliability Test
- Rework

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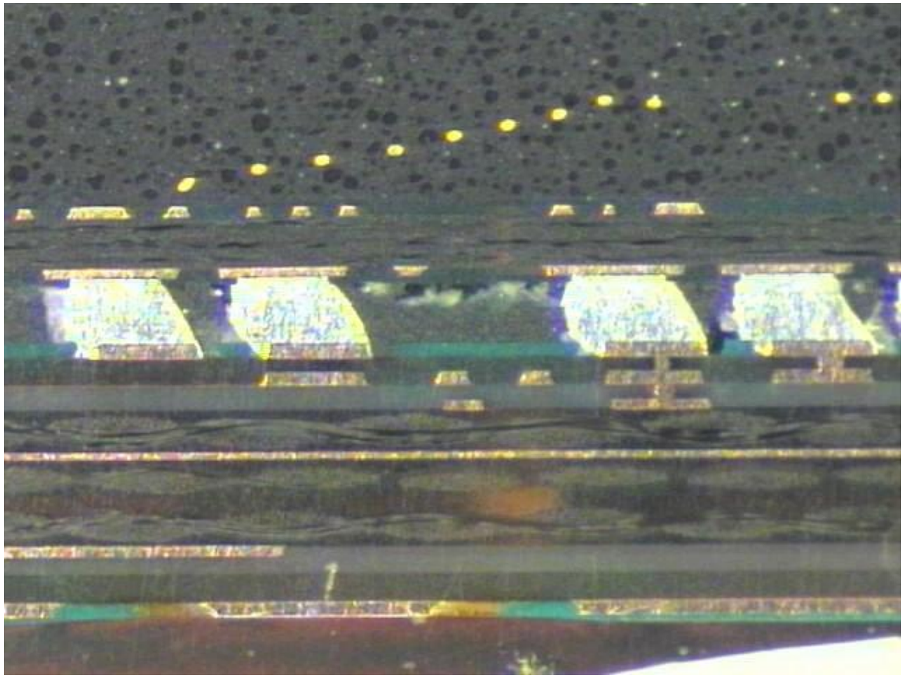
PWB - KX2

- 8 Layer PWB
- Stacked Microvias
- Layer 1-2, Layer 6-8
- 0.8mm +/- .08mm
- Layer 2-3, 6-7 RCC



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Package Specification

- MSM 5100
- Ball Grid Array
- Ball Diameter 0.40mm+/- .05mm
- 0.8mm pitch
- 208 pins
- Tin Lead solder Balls
- 63 tin/37 Lead- 183C
- 12.8mm X12.8mm

- MSM 6100
- Chip Scale Package
- Ball Diameter 0.3mm+/- .05mm
- 0.5 mm pitch
- 341 pins(285 I/O)
- Lead Free Solder Balls
- (96.5 Tin3.5 Silver 0.5 Copper- 217C
- 11.5 mm X 11.5 mm

Soldering Process Flow

- **Current Process**

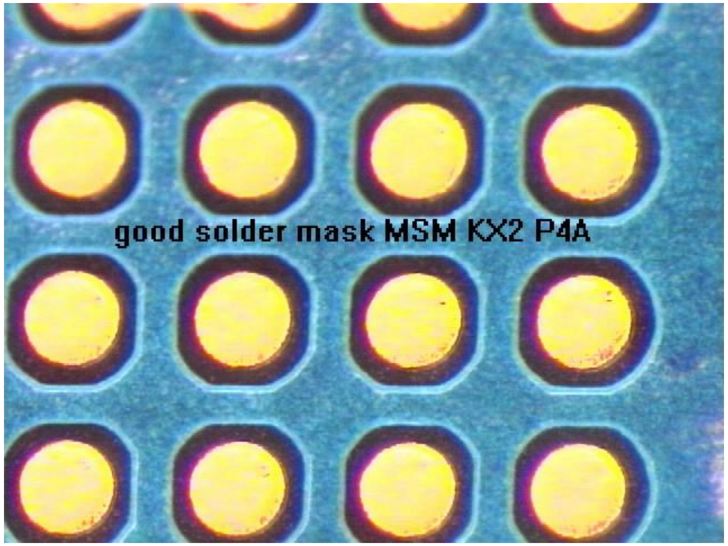
Lead Free Package +Lead Based Paste

- **Future Process**

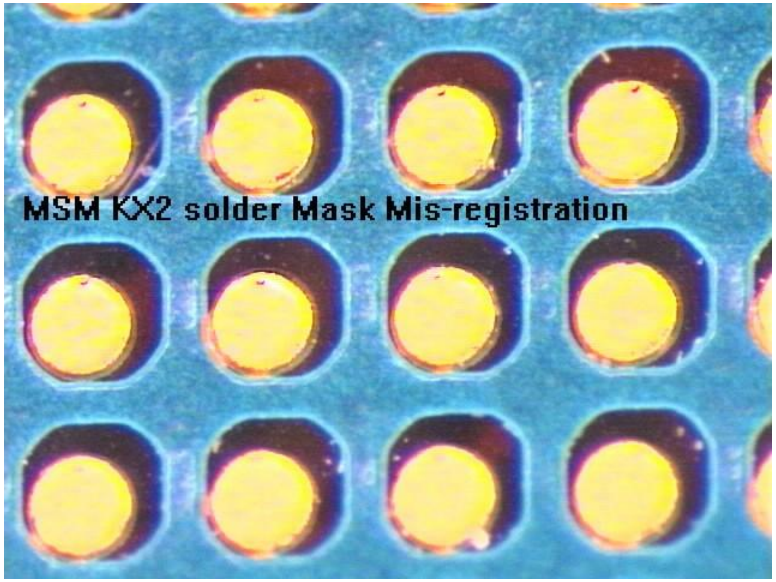
Lead Free Package + Lead Free Paste

- Soldering lead free passives, IFR, and BGA

Solder Mask Registration

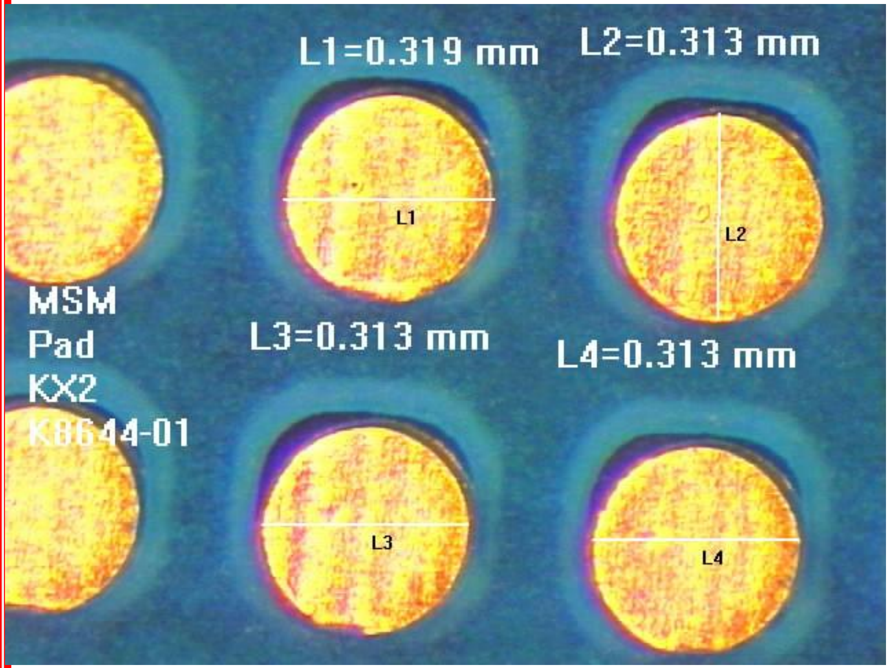


Good Registration

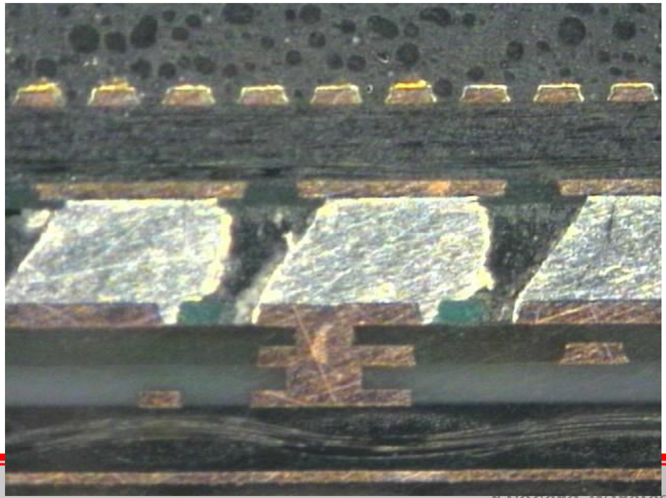


Mask Misregistration

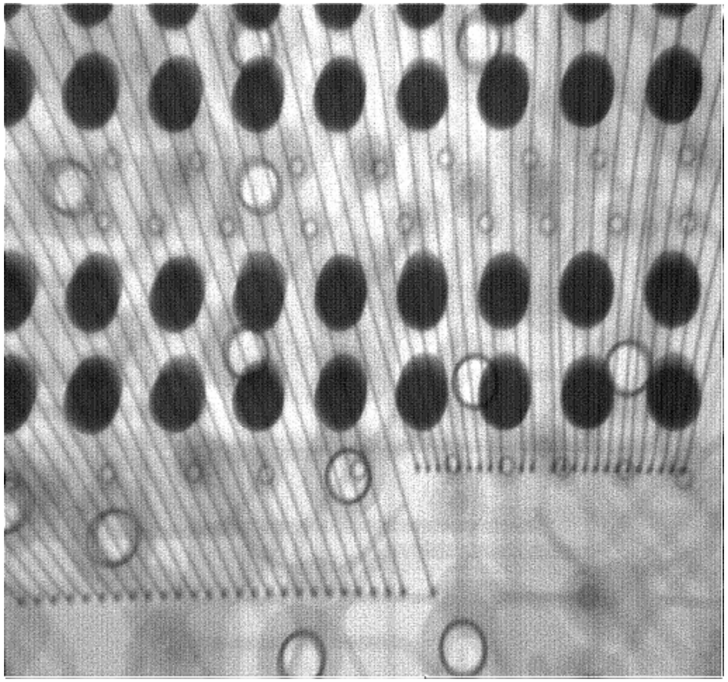
MSM Land Pattern



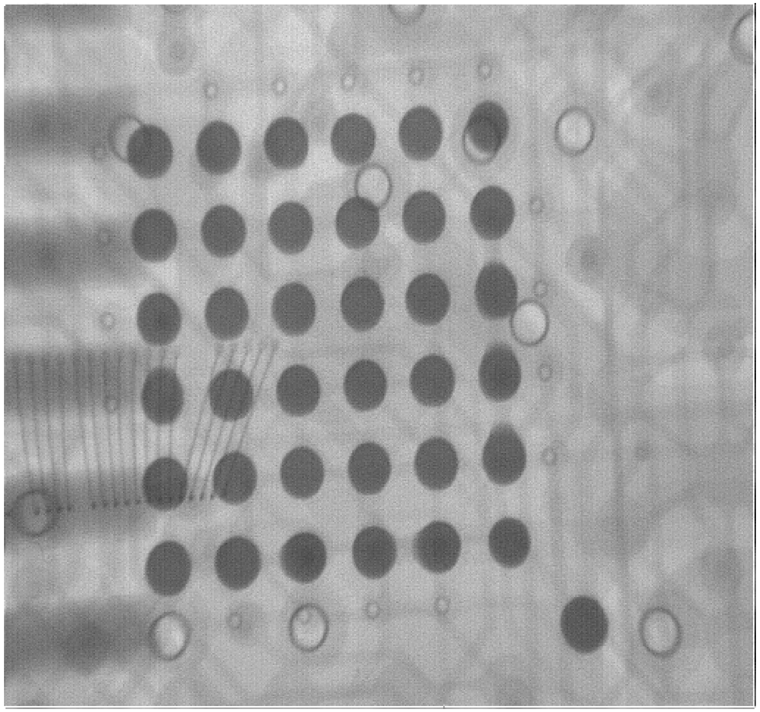
- MSM Land Pattern
- 0.3 MM
- Less Contact Area
- Lifted Lands
- Corner Pin Crack



X- Ray Images



X-Ray - Misalignment



X-Ray - Aligned

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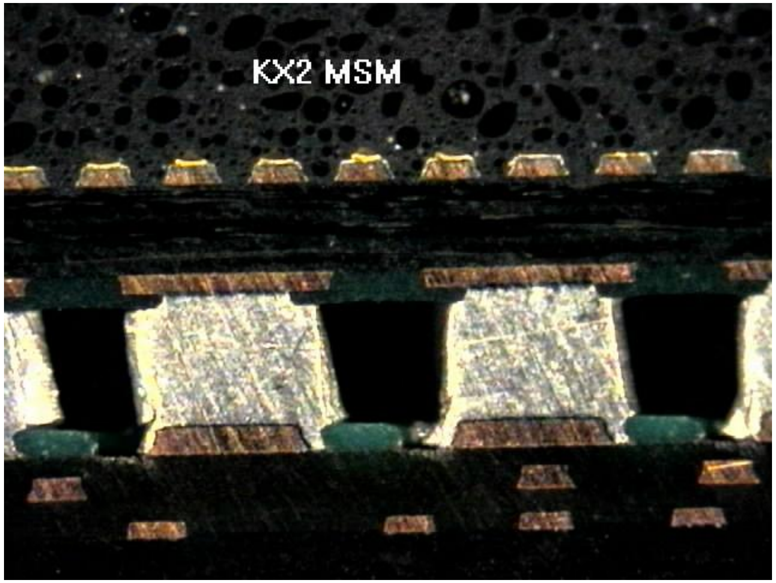
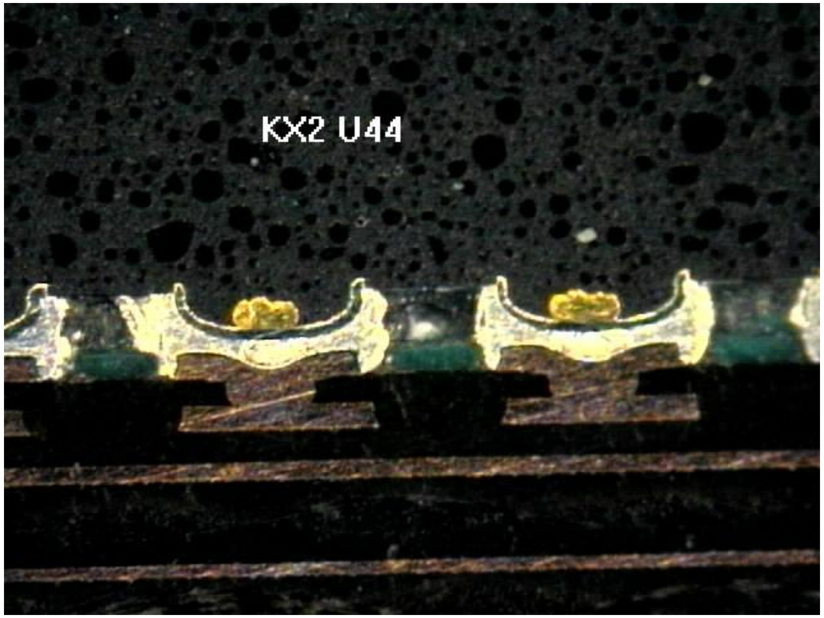
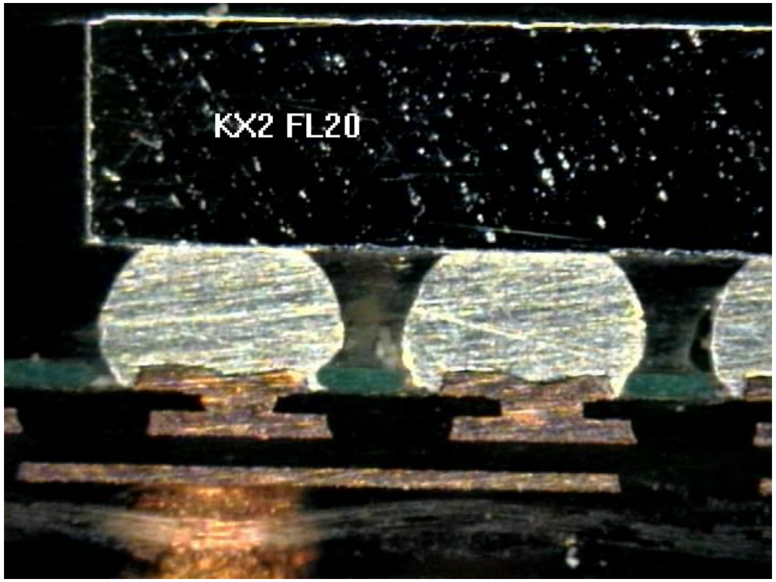
Post Reflow X-Sections



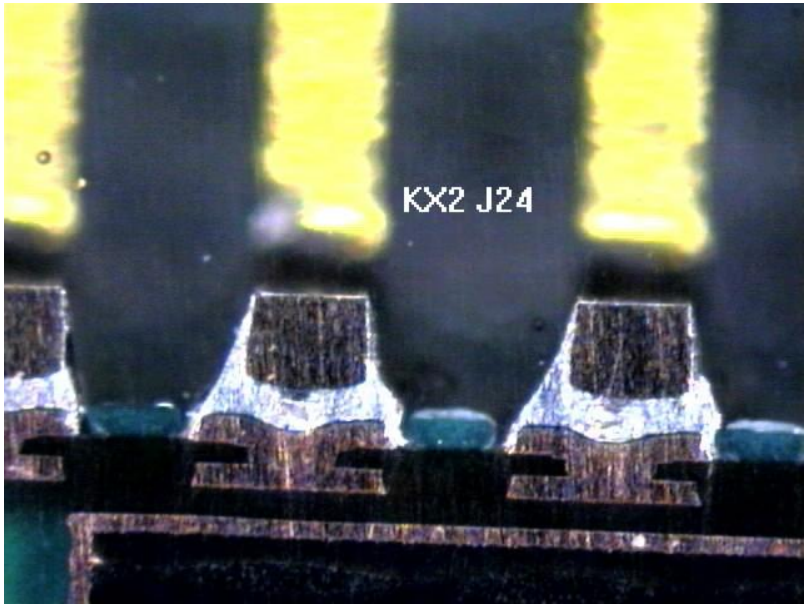
MSM Solder Joint-SideA



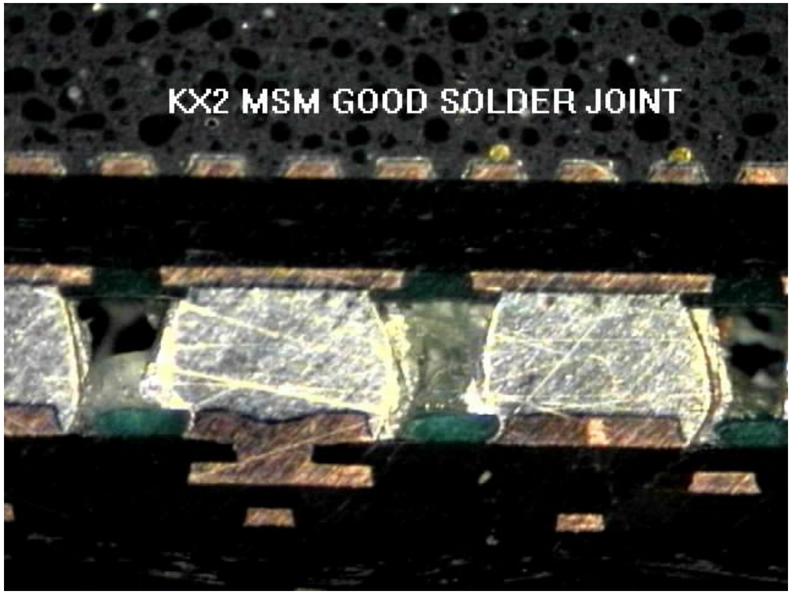
IFR Solder Joints



ESD Filter



Connector J24



MSM symmetric

MSM Misaligned

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Reflow Profile

- Peak temp. 226C
- Modifying to 230C
- Re-evaluate X-sections at new peak temp.

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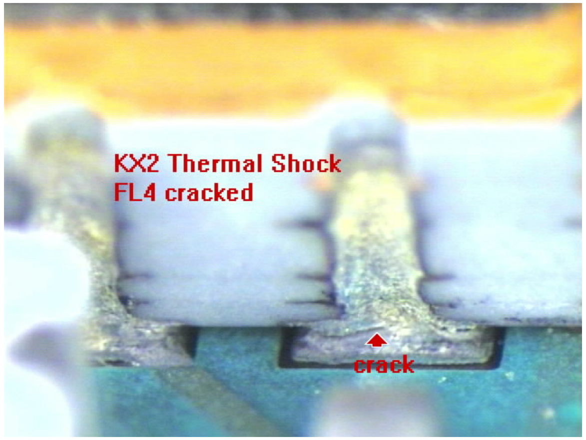
Reliability Test

- Thermal Shock - -25 to +125C 500 Cycles 20 min.dwell
  - Ceramic Filter crack- rated for 85C
- Temp. Humidity - 85C/85% RH - 500 Hours
  - All Pass



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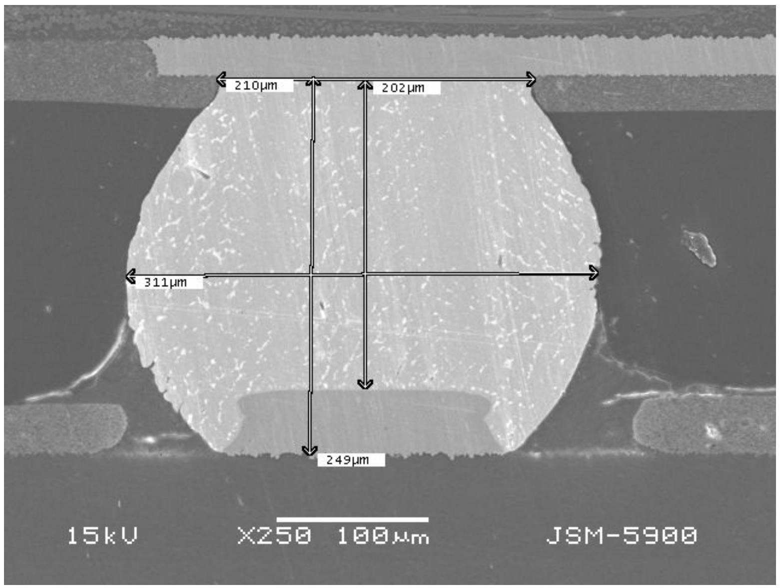
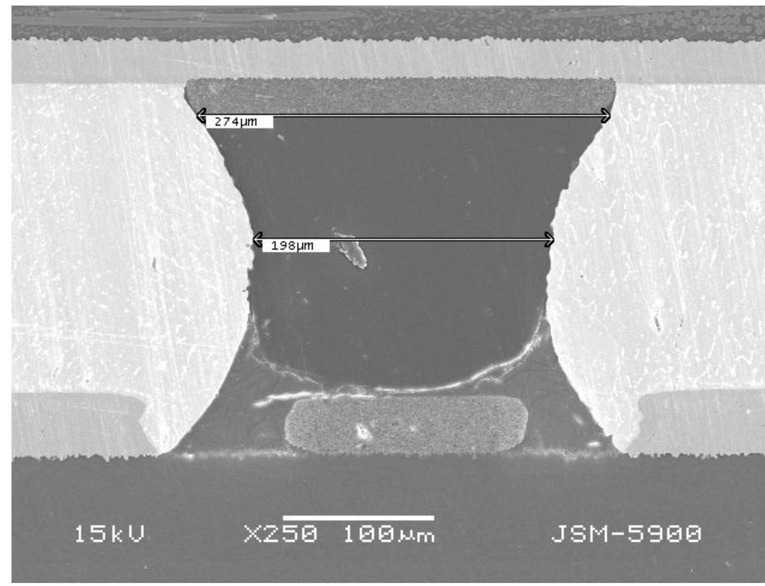
Diffusion of Lead on Solder Joint



Ball Size Measurements



Uniform Diffusion of Lead on the Solder Ball

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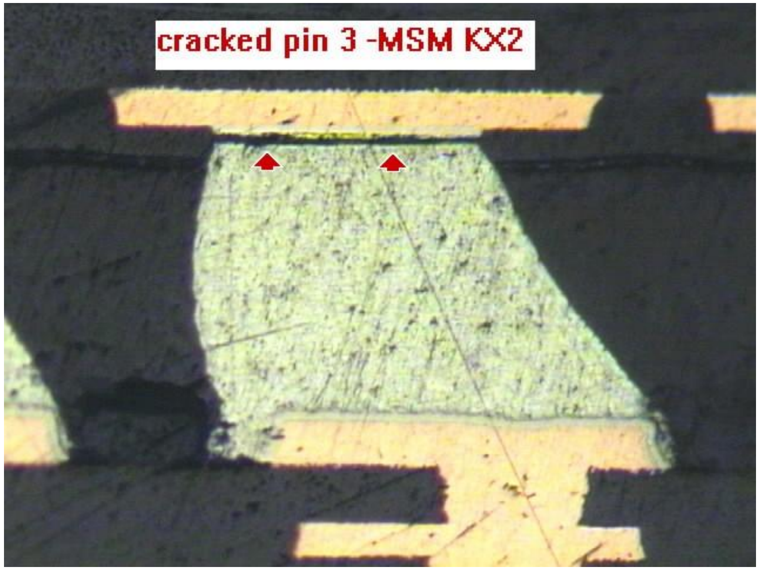
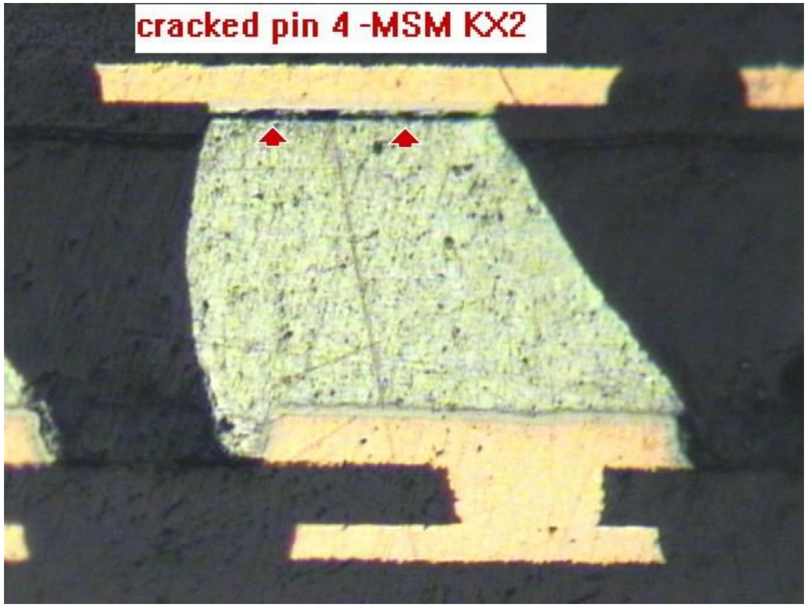
Cracking of Misaligned MSM (27- 41% Misalignment)



Package Side Pin Cracks after Control+Random drop



MSM Pin Cracks - No Underfill . Control +Random Drop

KYOCERA WIRELESS CORP.

Conclusion

- Profile Optimization to balance Side A /Side B
- Process Capability for Placement needs to be Established at Pilot
- X-Ray Acceptance Criteria Defined
- Rework Process Qualification
- Rework Training
- Underfill Process Definition