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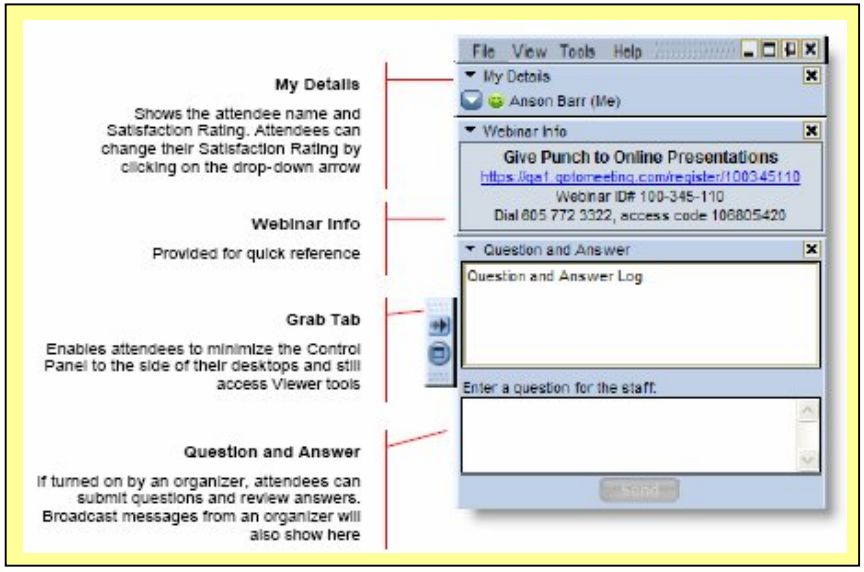

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Definition – Forward Compatibility

- Using lead-free solder with leaded components

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Definition – Backward Compatibility

- Using Pb free components in Sn/Pb process

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Issues

- Will the tin-lead solder process completely reflow the lead-free ball on BGA components.
- Will the flux be able to sustain the elevated temperatures of the Lead-Free Process

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Issues

- Lead free BGA's were not recommended for Sn/Pb assembly using temperature below 220°C (428°F) because solder joints were poorly formed if the balls did not melt.

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Reality

- Mixed assemblies are going to be made during the transition period, so we need to find out if they are reliable based upon the demands of the product.

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Experiment #1
Evaluation Parameters

- Boards, HASL and OSP
- Components, Tin and Tin/Lead
- Solder, SAC 305 and Tin/Lead

Investigation of the Forward and Backward Compatibility of Solder Alloys With Component Finishes for HASL and OSP PCB Finish, Anand Kannabiran, Elavarasan T. Pannerselvam, and Prof. S. Manian Ramkumar, Center for Electronics Manufacturing and Assembly, Rochester Institute of Technology, Rochester, NY

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Tests Conducted *1

- Isothermal, to simulate creep failures
- Thermal Shock, to simulate mechanical fatigue
- Shear Test, to test residual joint strength
  - Board finishes were OSP and HASL

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Isothermal Aging

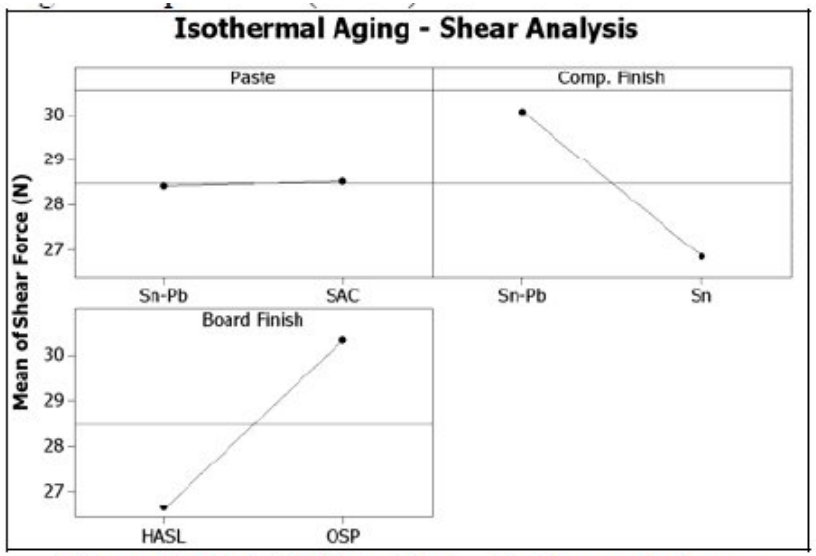

Figure 5 Main Effects Plot – Isothermal Aging

- Sn/Pb and SAC alloys have identical behavior regardless of component or board finish
- The Sn-Pb terminations performed better than the Sn.
- The OSP board had better shear strength than the HASL

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Isothermal Aging

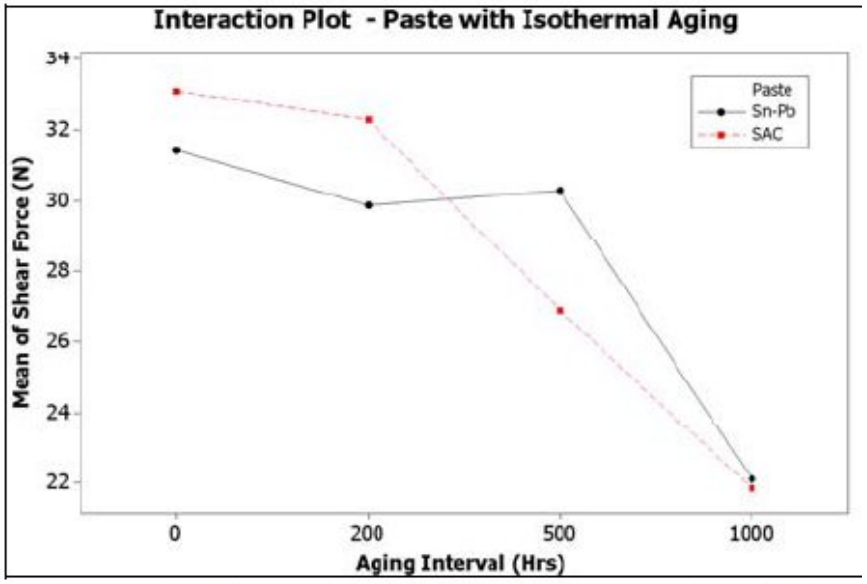

Figure 6 Interactions plot – Isothermal aging

- Plot shows a higher rate of degradation of SAC paste on long exposure to higher temperatures

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Thermal Shock

- Sn/Pb paste and Sn/Pb components had the highest shear force
  - Both HASL and OSP finish had similar performance when subject to thermal shock regardless of paste and component termination finish in the solder joint.

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Shear Tests

- OSP boards with Sn/Pb components had best results with either Sn/Pb or SAC solder paste

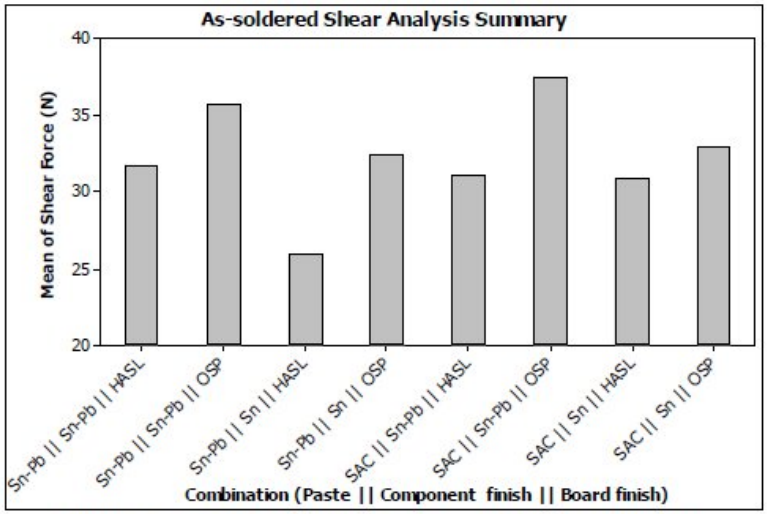

Figure 4 Joint Strength – As-soldered condition

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Conclusion of this evaluation

- Isothermal aging
  - Both alloy performed equally
  - OSP had higher joint strength than HASL
  - Sn/Pb joints degraded less than Sn joints
- Thermal Shock
  - SAC alloys performed better when subjected to fatigue loading
  - Backward compatible units stood more shock than all other combinations.

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Recommendations of this evaluation

- BGA components, backward compatibility or SAC assembly is recommended.
- For chip components, SAC paste assembly of Sn/Pb component on OSP boards is recommended for better reliability and longer life.

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Experiment #2
Evaluation Parameters

- To define what degrees of solder alloy mixing exist on the reliability of SAC 305 BGA assembled with Sn/Pb eutectic solder paste.
- Board finishes were HASL and ImAg

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Investigations Revealed

- Different amount of solder intermixing due to reflow parameters
- Sn-Pb/Sn-Pb assemblies were more reliable
- Predominant failures of mixed solder joints was interfacial cracking through the Pb-rich phase near the intermetallic layer

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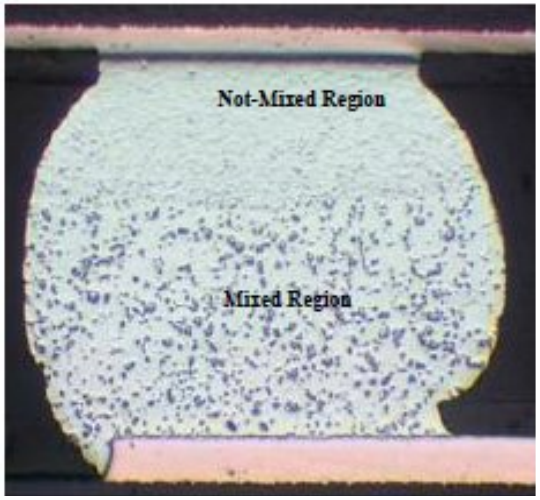
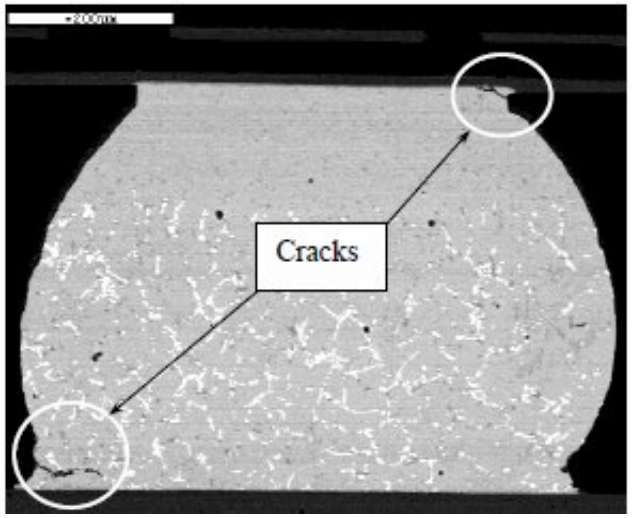
Backward Process/Component Compatibility



Typical picture of a BGA with partial mixing. Some of the locations on the component had complete mixing of the alloys



Solder joint microstructure after Thermo-mechanical fatigue

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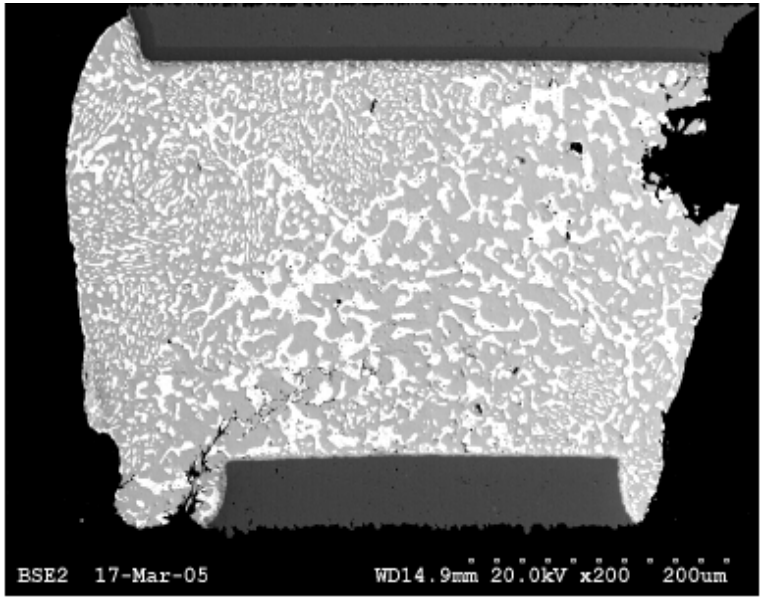
Sn/Pb – Sn/Pb BGA Joint



SEM of solder joint after 1000 cycles.

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#2 Conclusions

- Complete reflow achieved when peak temperature reached 218 – 222°C
- All mixed, partially or fully mixed memory assemblies, fracture interfacially at the board side after Accelerated Testing Cycle
- Interfacial fractures were attributed to Pb segregation at the interface
- The control Sn-Pb/Sn-Pb assemblies showed better reliability than mixed memory assemblies

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Experimental Results

- The dissolution of Lead into the solder ball was not consistent across individual BGA components.
- The predominant failure mode was interfacial cracking through the Lead rich phase near the intermetallic area.
- Stress and Lead rich phase segregation was the causal effect for the shortened thermal-mechanical fatigue life of the solder joints.

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Experiment #3
Evaluation Parameters

- Investigate solder joint reliability of SAC BGA component attached with eutectic Tin/Lead solder

Solder Joint Reliability of Sn-Ag-Cu BGA Component Attached with Eutectic Pb-Sn Solder Paste, *Fay Hua, Raiyo Aspandiar, Tim Tothman, Cameron Anderson, Greg Clemons, Mimi Klier, Intel Corp, materials technology Operation, 3065 Bowers Ave. Santa Clara, CA 95054, Package Technology Development, 1900 Prairie City, Folsom CA 95630, Intel Corp., Assembly Technology Division, 5000 W. Chandler Blvd, Chandler, AZ 85226, Intel Corp., Systems Manufacturing Technology Division, 5200 NE Elam Young Parkway, Hillsboro OR 97124*

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Experimental Parameters

- Various thermal profiles
- Peak reflow of 208 and 222°C with soak and straight profile
- Temperature cycling -40C to 125°C for 30 minutes/cycle
- Drop testing
- Time above liquidus, 60 – 90 sec and 90 to 120 seconds
- Board finish, ENIG and OSP

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Initial Results

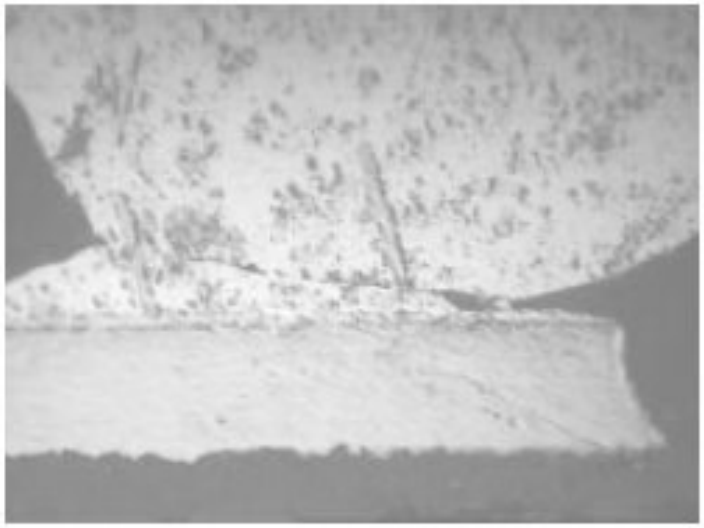

Figure 5. Solder joints made by 208°C peak/60-90TAL ramp profile.

- Lower peak temp and shorter TAL did not result in acceptable solder joints

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Results

- Drop test failures are either vias cracking or clean interfacial separation at the solder to PCB interface
- All the units failing with the same failure mode on ENIG boards
  - Confirmed as Black Pad related
- Early temp cycle failures occurred with 208°C high temp, 60 -90 above 183°C, ramp profile, no presoak

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Results

- Assemblies with all Lead-Free joints and joints with 63/37 BGA ball attached with SAC solder paste on ENIG and processed at 250°C showed very low early failure rate.
- Data suggest that board level reliability goals are met for Lead-free balls using 63/37 solder paste on OSP board surface finish under certain process conditions.

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Experiment #4
Evaluation Parameters

- Check:
  - Elevated Reflow Profile
  - Component Reballing
  - Post Assembly Rework

Backward Compatibility, Are We Ready – A Case Study, *Indraneel Chatterji, Solectron Inc, Charlotte, NC*

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Parameters

- Board Finish – OSP
- 2000 ATC cycles, temp range 0 to 100°C & 10 minute dwell time
- Tin/lead solder paste, water soluble flux
- SAC 305 BGA components

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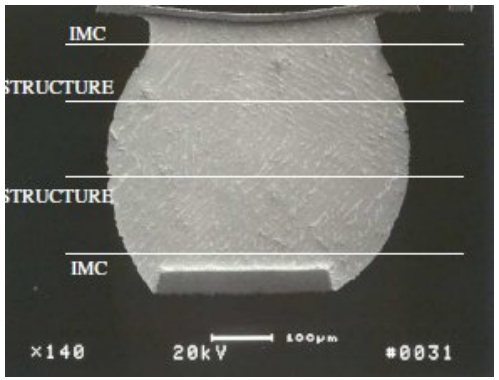
Results

- Mixed assembly, peak temp 208 -209°C
  - Good ball collapse
  - No cracking of solder joints
  - First cracks after 800 ATC cycles
    - Cracks initiated from the edge into the bulk solder



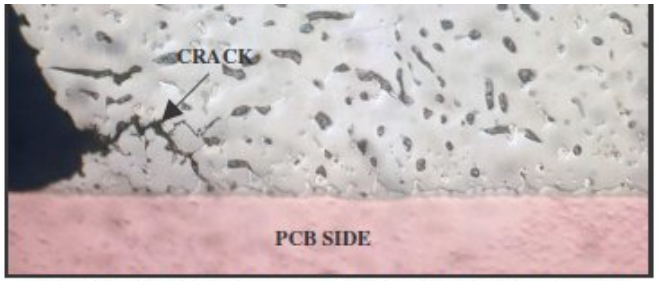


Figure 6. Mixed Assembly Solder Joint Crack after 2000 Cycles

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Results

- Mixed assembly – peak temp 222°C
- TAL of 95 sec.
- Homogeneous mixing of tin-lead paste
- Granular Pb dendrites were observed on the component side of the solder joint

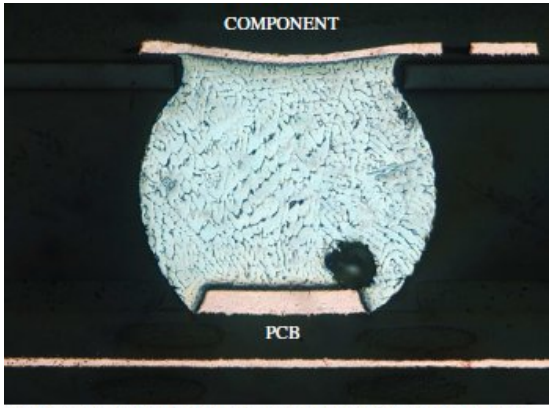

Figure 12. Mixed Assembly at Elevated Temperature at Time Zero (222 deg C)

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Conclusions

- Percent solder joint cracking in this study was lesser for mixed assembly reflowed at 222°C compared to tin-lead assemblies
- With Tin-lead assemblies the solder joint failed a long way across the ball diameter at the ball/package interface after 1500 and 2000 cycles.

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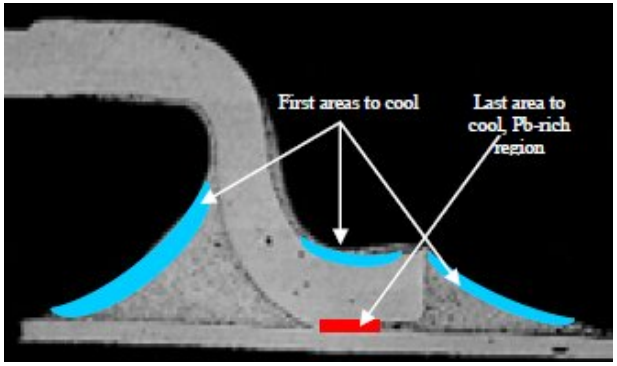
Lead Contamination, Forward Compatibility

"When using a lead-free alloy to solder Sn/Pb Coated component leads, Pb can actually create voids in the solder joint that can result in joint failure."



Adapted from: *Lead-Contamination in Lead-Free Electronics Assembly*
By Karl Seeling and David Suraski

- Lead as an impurity goes to the last area of the joint to cool.
- This forms a pocket and disturbs the grain structure.
- The resultant lead rich areas have a lower melting temperature and could cause dewetting during soldering

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Results and My Recommendations

- Tin lead solder paste and SAC alloy components i.e. BGA appears to work if the proper procedures have been thought out and evaluated.
  - Long dwell times above TAL.
    - > 95 seconds
  - Reflow temp > 220^{o}C
- OSP boards had better results than the HASL boards
- ENIG had some susceptibility due to potential of Black Pad phenomena.

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Results and My Recommendations

- Many of the articles have references to other experiments and positions on those recommendations

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Results and My Recommendations

- Commercial application it appears to be a go condition
- Some papers discuss hi-reliability and do not recommend mixed metallurgy.
  - Go with either tin/lead and tin/lead or
  - Lead-free and lead-free

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Results and My Recommendations

- Don’t do it unless it is necessary to meet customer demands
- Check with customers to find out what kind of evaluations to conduct to verify goodness of products
- Each application is unique and must be evaluated as such

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now your questions

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References:

1. ***Investigation of the Forward and Backward Compatibility of Solder Alloys With Component Finishes for HASL and OSP PCB Finish,*** *Anand Kannabiran, Elavarasan T. Pannerselvam, and Prof. S. Manian Ramkumar, Center for Electronics Manufacturing and Assembly, Rochester Institute of Technology, Rochester, NY*

2. ***Reliability of Mixed Solder Interconnects – Case Studies****, Adam R. Zbrzenzny, Polina Snugovsky, Tanya Lindsay, Ross Lau, Celestica Inc. ATI Technologies, Toronto, Ontario, Canada.*

3. ***Solder Joint Reliability of Sn-Ag-Cu BGA Component Attached with Eutectic Pb-Sn Solder Paste****, Fay Hua, Raiyo Aspandiar, Tim Tothman, Cameron Anderson, Greg Clemons, Mimi Klier, Intel Corp, materials technology Operation, 3065 Bowers Ave. Santa Clara, CA 95054, Package Technology Development, 1900 Prairie City, Folsom CA 95630, Intel Corp., Assembly Technology Division, 5000 W. Chandler Blvd, Chandler, AZ 85226, Intel Corp., Systems Manufacturing Technology Division, 5200 NE Elam Young Parkway, Hillsboro OR 97124*

4. ***Backward Compatibility, Are We Ready – A Case Study****, Indraneel Chatterji, Solectron Inc, Charlotte, NC*

5. ***Solder Joint Formation With Sn-Ag-Cu and Sn-Pb Solder Balls and Pastes,*** *Polina Snugovsky, Zohreh Bagheri, Matthew Kelly Marianne Romansky, Celestica International Inc. Toronto, Ontario, Canada*

6. ***Microstructure and Properties of Sn-Pb Solder Joints with Sn-Bi Finished Components,*** *P. Snugovsky, J. McMahon, M. Romansky, Celestica Inc.*

7. ***The Impact of Reflowing A Pbfree Solder Alloy Using A Tin/lead Solder Alloy Reflow Profile on Solder Joint Integrity,*** *David Hillman, Matt Wells, Kim Cho, Rockwell Collins, Cedar Rapids Iowa.*

8. Adapted from: ***Lead-Contamination in Lead-Free Electronics Assembly,*** By Karl Seeling and David Suraski

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