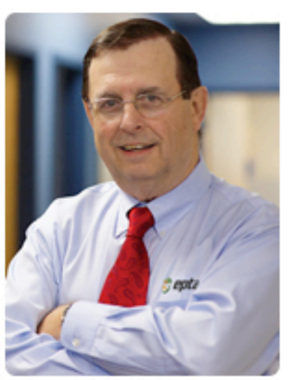

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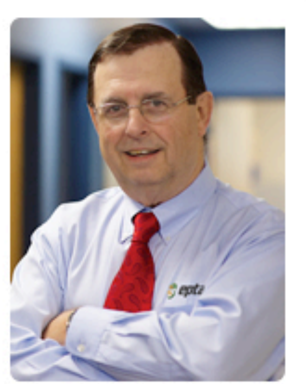
# IPC -7095C Design and Assembly Process Implementation For BGAs



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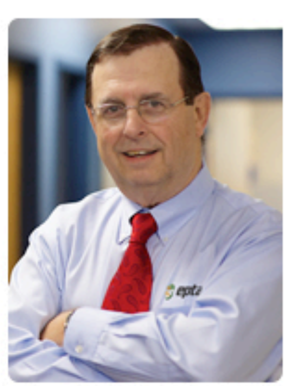
# Overview

With the introduction of BGA components, things had to change:

- New design
- New assembly process
- New repair process
- New inspection techniques

All information in this presentation is adapted from the IPC-7095C document



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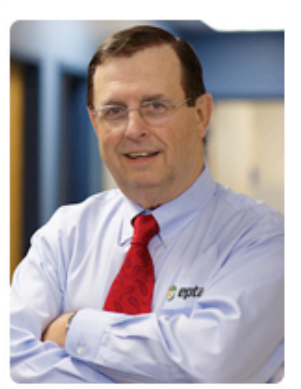
# Scope

- Covers the challenges for implementing all types of BGA components
- Information in document focuses on inspection, repair and reliability with BGA components



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# Purpose

- To provide practical and useful information to users of BGA components
- Target audience is managers, design and process engineers, operators and technicians

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# Intent

- This document identifies many of the issues involved which will influence the implementation of a robust BGA assembly process
- The accept/reject criteria is found in J-STD-001 and IPC-A-610

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# Applicable Documents

There is a list of

- 27 IPC Documents
- 16 JEDEC Documents

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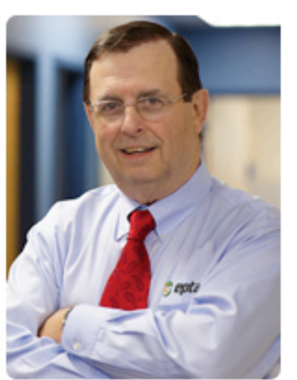
# Why BGA Components

- Peripheral devices with 1.00 mm pitch have become commonplace, however these packages cannot accommodate more than 84 pins.
- Larger pin count devices require lead pitches on 0.65 mm, 0.5 mm or 0.3 mm
- Therefore at these pitches leads are very fragile and susceptible to damage.
- The BGA eliminated lead and coplanarity problems



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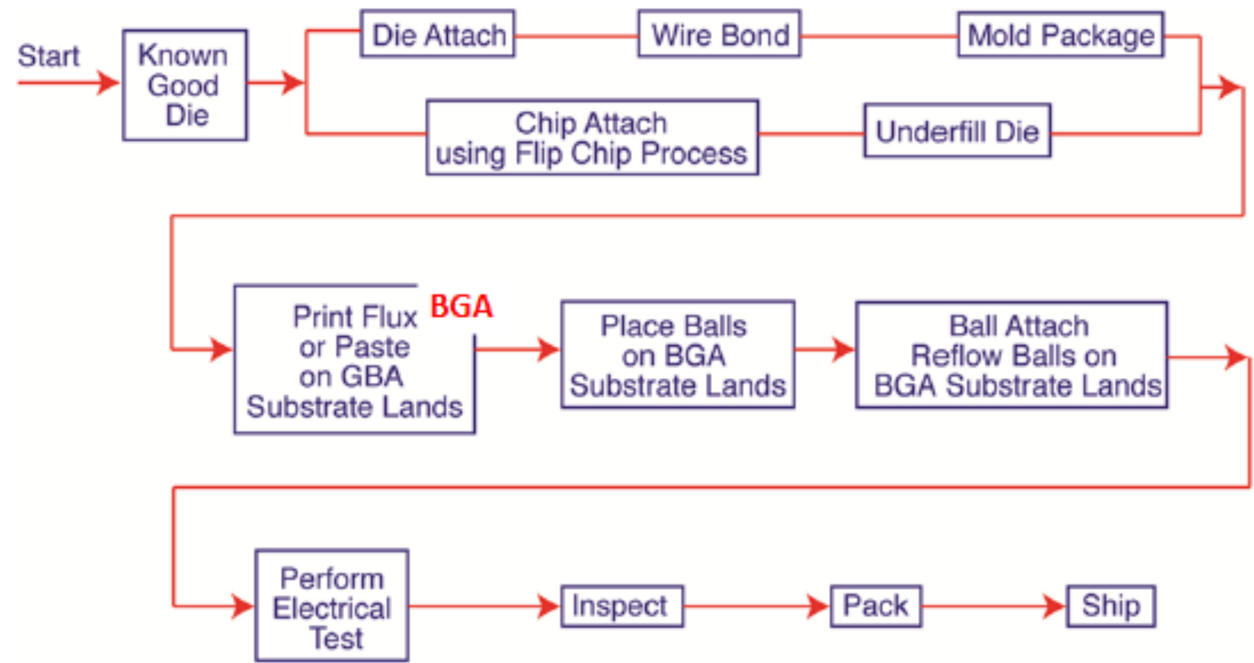
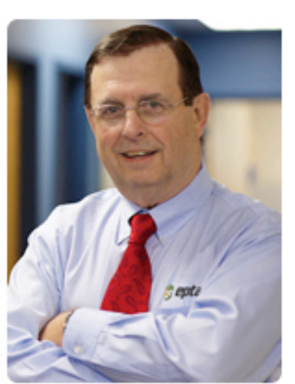
# BGA Package Manufacturing Process





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# Infrastructure

- Land Patterns and circuit board considerations.
- Technology comparison

| MCM | Technology Description | Attributes |
|---|---|---|
| Type 1 | Common Technology Package | Multiple same type chips, in plane |
| Type 1S | Common Technology Package | Multiple same type chips, stacked |
| Type 1F | Common Technology Package | Multiple same type chips, folded |
| Type 2 | Mixed Technology Package | Mixed IC technology package, in plane |
| Type 2S | Mixed Technology Package | Mixed IC technology package, stacked |
| Type 2F | Mixed Technology Package | Mixed IC technology package, folded |
| Type 3 | System in Package | Mixed ICs and discrete devices, in plane |
| Type 3S | System in Package | Mixed ICs and discrete devices, stacked |
| Type 4 | Optoelectronic System Package | Mixed technology for optoelectronics |

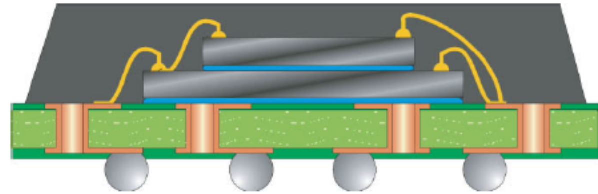
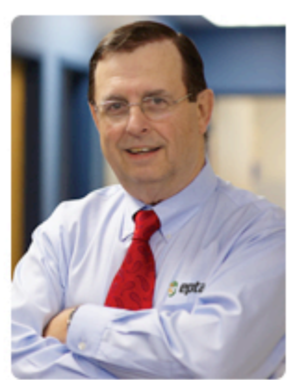


Figure 3-4 MCM type 2S-L-WB

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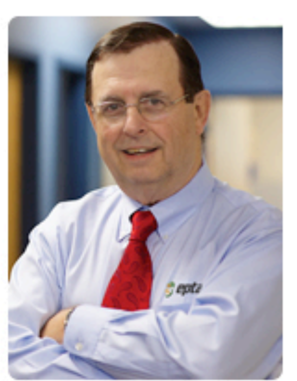
# Conductors Between BGA Connections

- This gets into the size of the BGA and the number of traces which can be used between the balls of the BGA component

**Table 3-2 Number of escapes vs. array size on two layers of circuitry**

| Array Size | Total Leads | Number of Conductors Between Vias (•\|•) | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| | | •\|• | •\|\|• | •\|\|\|• |
| 14 X 14 | 196 | 192 | 196 | 196 |
| 16 X 16 | 256 | 236 | 256 | 256 |
| 19 X 19 | 361 | 272 | 316 | 352 |
| 21 X 21 | 441 | 304 | 356 | 400 |
| 25 X 25 | 625 | 368 | 436 | 496 |
| 31 X 31 | 961 | 464 | 556 | 640 |
| 35 X 35 | 1225 | 528 | 638 | 736 |



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# Conductor Width to Pitch Relationship

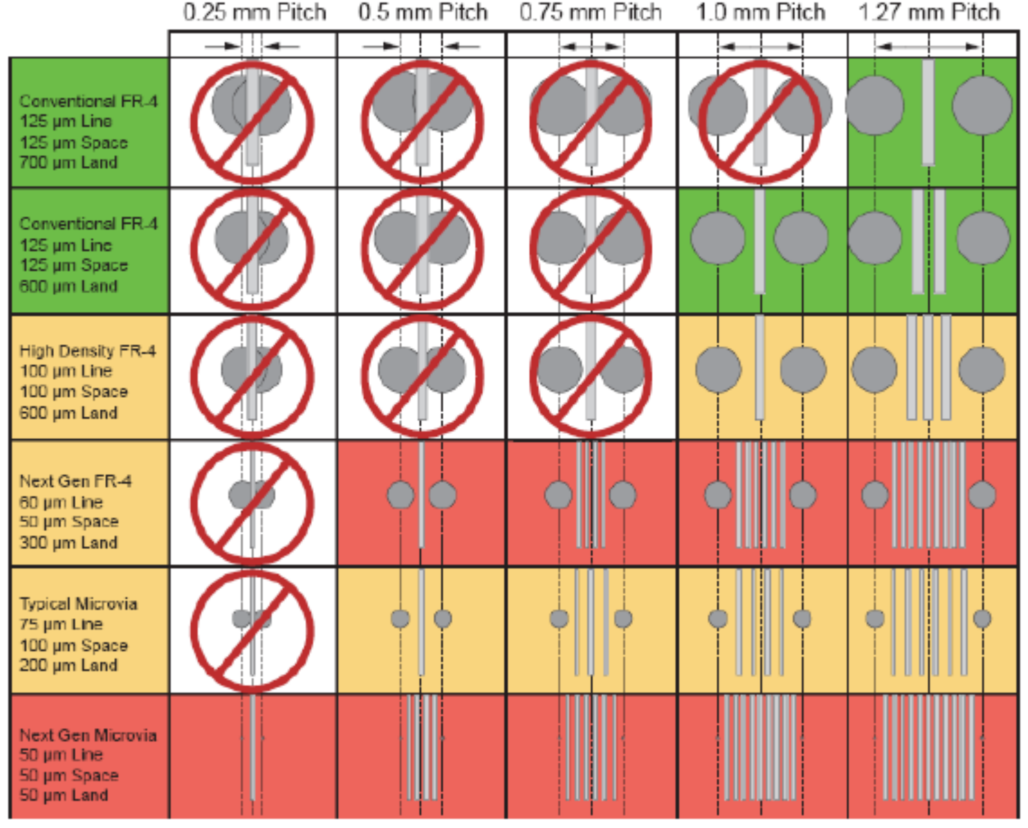
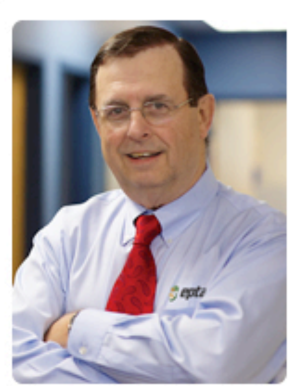



Figure 3-5 Conductor width to pitch relationship



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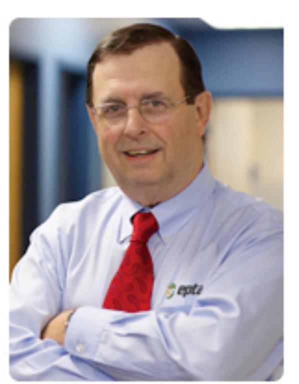
# Infrastructure

- Assembly Equipment Impact
- Stencil Requirements
- Inspection Requirements
- Test

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# Limitations and Issues

- Visual inspection
- Moisture sensitivity
- Rework
- Cost
- Availability
- Voids in BGA
- Open joints
- Head-on-Pillow phenomenon
- Standards and their adoption
- Reliability concerns

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# Limitations and Issues

3.5.8 Pad Cratering – defined as a separation of the pad from the PCB resin/weave composite or within the composite immediately adjacent to the pad, also know as "laminate crack"

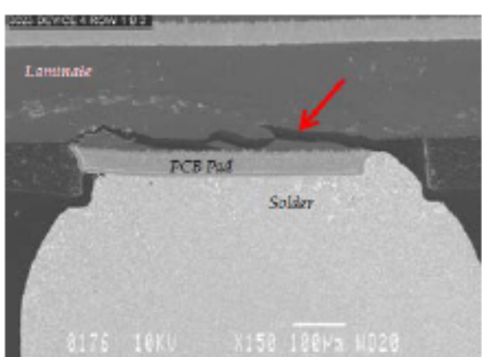
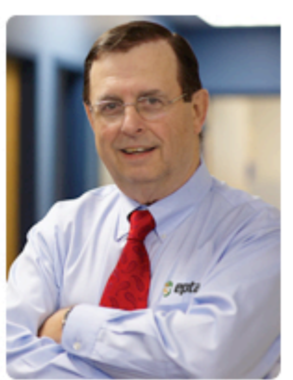



**Figure 3-9 Examples of Pad Cratering**



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# Limitations and Issues

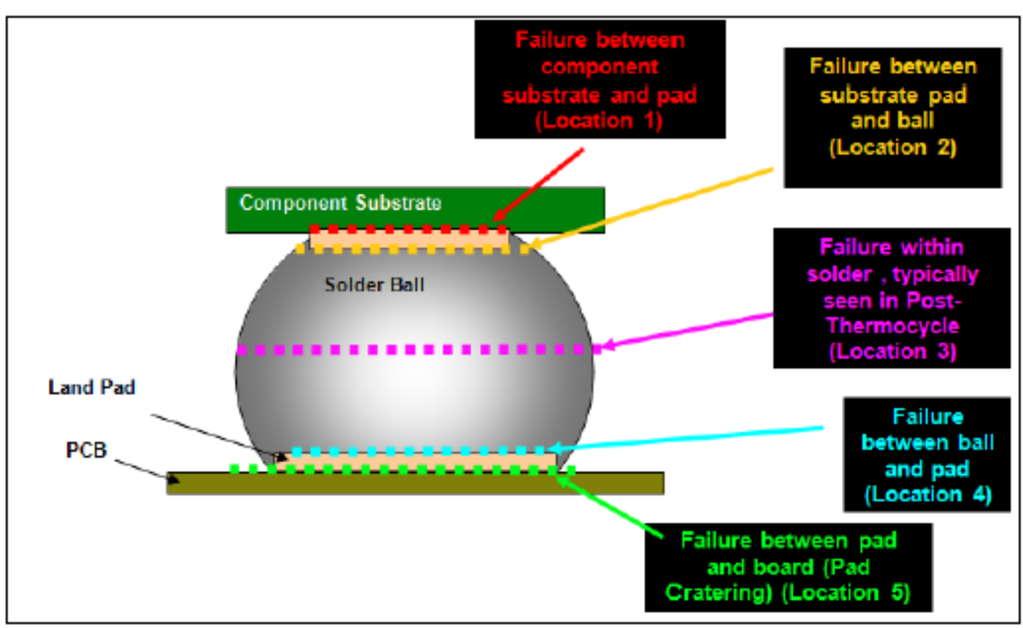
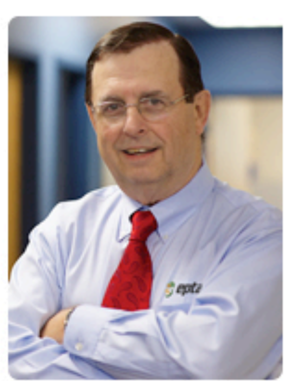



Figure 3-10 Various Possible Failure Modes for a BGA Solder Joint



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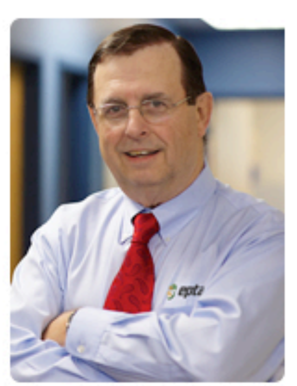
# Component Consideration

4.1 Semiconductor Packaging Comparison and Drivers

4.2 Die Mounting in the BGA Package



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# BGA Standards

## 4.3.1 Industry Standard

- BGA Package
- Fine Pitch BGA Package
- Die Size
- Ball Pitch
- Land Pattern Approximation
- BGA package outline
- Ball size relationships
- Package on Package
- Coplanarity

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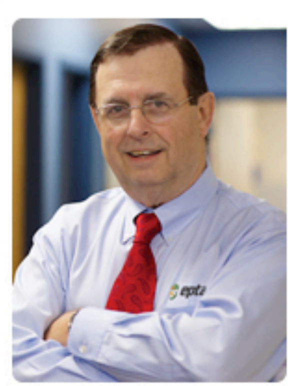
# Component Consideration

## 4.4 Component Packaging Style Consideration

- Base Material
- Solder ball Alloy
- Ball attachment process
- Ceramic BGA, Column Grid Array
- Multiple Die packaging



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# Component Consideration

- 4.5 BGA component and Sockets
- 4.6 Construction Materials
- 4.7 Package Design
- 4.8 Acceptance Criteria and shipping Format

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# Boards and Other Mounting Structures

Section 5.0 covers:

- Laminates or mounting structures
- Laminate properties
- Surface Finishes
    - Solderable Coatings

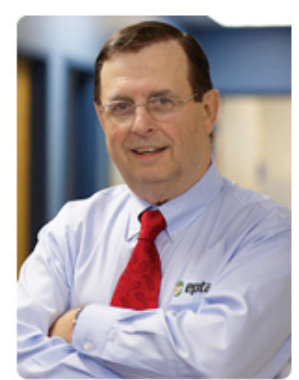

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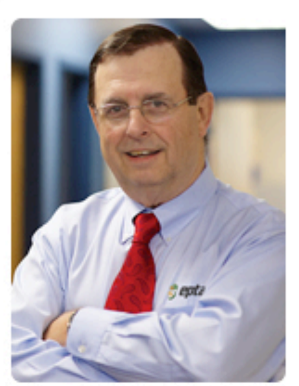
**Table 5-2 Key attributes for various board surface finishes**

| | HASL SnPb/SnCu* | OSP | Electroless Ni/Immersion AU | Electrolytic Ni/Electroplated AU | Immersion Silver** | Immersion Tin |
|---|---|---|---|---|---|---|
| Shelf Life proper Handling | 1 Year | 6 Months | > 1 Year | > 1 Year | 6 Months | 6 Months |
| Handling | Normal | Avoid physical contact | Normal | Normal | Avoid physical contact | Avoid physical contact |
| SMT land Surface topology | Domed/Flatter | Flat | Flat | Flat | Flat | Flat |
| Multiple assembly reflow cycles | Good, although intermetallics increase/need robust laminate | Fair, better with thick coatings; may see bare copper if reflowed with lead-free solder paste | Good | Good | Good | Good |
| Hole fill after multiple reflow cycles | No Concerns | May have problems after 2x reflow. | No concerns | No concerns | No concerns | May have problems after 2x reflow. |
| Use on thick PCBs | Barrels difficult to fill and clear | PTH fill concerns | Improved barrel reliability | Improved barrel reliability | PTH fill concern | PTH fill concern |
| Use in thin PCBs | No, prone to warping/Avoid | Yes | Yes | Yes | Yes | Yes |
| Solder joint reliability | Good | Good | BGA "black pad" concerns<br>Sporadic brittle fracture | Gold embrittlement concerns | Planar microvoid concerns | Good |
| Card edge contacts | Additional plating operation | Additional plating operation | Additional plating operation | No additional plating | Additional plating operation | Additional plating operation |
| Wire bonding | No | No | No | Yes | No | No |
| Test point probing | Good | Poor, unless solder applied during assembly | Good | Good | Good | Good |
| Exposed Copper after Assembly | No | Yes | No | No | No | No |
| Switches/Contacts | No | No | Yes | Yes | Yes | No |
| Waste Treatment and Safety in PCB Fabrication | Poor/Fair | Good | Fair | Fair | Poor | Good |
| Process Control | Thickness control concerns | Fair | Phosphorus content concerns | Gold thickness control concerns | Micro-etch and plating concerns | Tin whisker concerns |
| Coating thickness/µm | 0.8 – 0.38 | 0.2 – 0.5 | 3-7/0.05-0.10 | .8 – 2.5 | 0.07 – 0.10 | 1.0 – 1.3 |
| General Cost Comparison | 1 | 0.4 – 0.6 | 2.0 – 3.0 | 1.2 – 1.5 | 1.1 – 1.6 | ~0.8 |

* Tin copper alloy is the preferred alloy for lead-free HASL

** For reflow operation >1 year if sealed in Moisture Membrane Bag (MMB)



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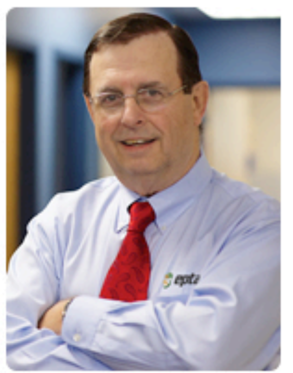
# Boards and Other Mounting Structures

## 5.4 Solder Mask

- Wet and Dry Film mask
- Photoimageable soldermask
- Via Protection

| | | |
|---|---|---|
| | | **Plugged and Covered Via (Type IV Via)** A Type III via with a secondary covering of material applied over the via . The plug and secondary covering material may be applied from either one side (Type IV-a) or both sides (Type IV-b) of the via structure. (IPC-4761 Fig.-5-4) |
| | | **Filled Via (Type V Via)** A via with material applied into the via targeting a full penetration and encapsulation of the hole. (IPC-4761 Fig. 5-5) |
| | | **Filled and Covered Via (Type VI Via)** A Type V via with a secondary covering of material (liquid or dry film soldermask) applied over the via. The covering material may be applied from either one side (Type VI-a) or both sides (Type VI-b) of the via structure. (IPC-4761 Fig. 5-6) |



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# Fine Pitch BGA Microvia In Pad Strategies

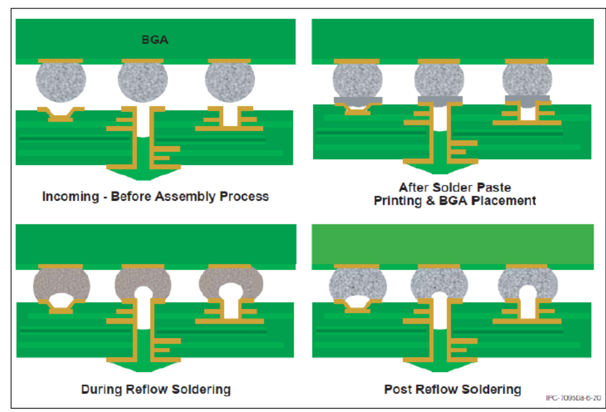



Figure 6-20 Via-in-pad process descriptions

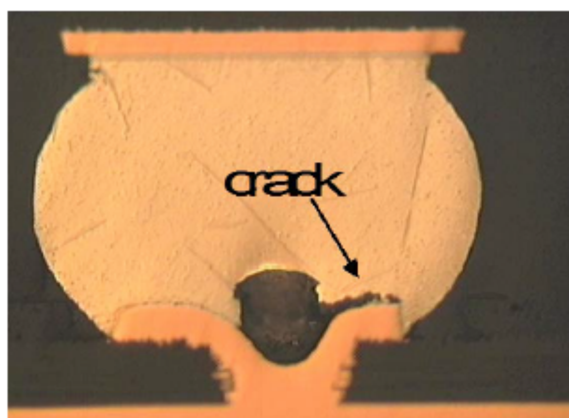
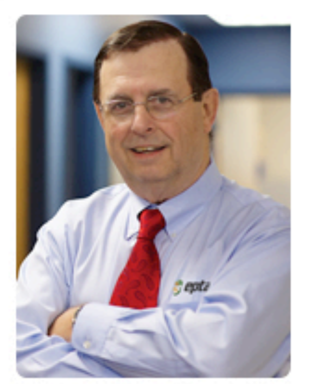



Figure 6-22 Microvia in pad voiding



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# PCB Assembly Design Considerations

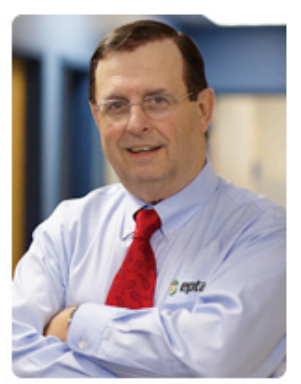
6.4 Impact of Wave Solder on Top Sided BGAs

6.5 Testability and test points

6.6 Other design for Mfg issues

6.7 Thermal Management

6.8 Documentation and electronic Data Transfer



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# Assembly of BGA to the PCB - Section 7

- Solder paste
  - Stencils
  - Powder Size
  - Paste volume
- Component Placement and Insp
- Reflow and profile

**Table 7-1 Particle size comparisons**

| Solder paste type | Mesh | Maximum particle size [μm] |
|---|---|---|
| Type 2 | -200/+325 | 75 |
| Type 3 | -325/+500 | 53 |
| Type 4 | -400/+500 | 38 |
| Type 5 | -500 | 25 |

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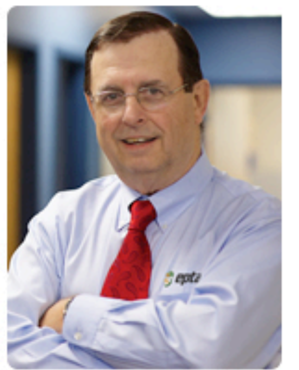
# Time and Temp Profiles

**Table 7-3 Profile comparison between SnPb and SAC Alloys**

| Profile Topic | SnPb Alloy Profile | Mixed/Backward Compatibility Profile | Pb-Free Alloy (SAC)/Forward Compatibility Profile |
|---|---|---|---|
| Alloy Solidus temperature | 183oC | 183oC/220oC | 217–220oC |
| Alloy soldering temp range | 210–220oC | 228–232oC | 235–245oC |
| Minimum peak reflow temperature ** | 205°C | 228oC | 230°C |
| Component ramp up rate | 2–4oC / second * | 2–4oC / second * | 2–4oC / second * |
| Component ramp down rate | 2–6oC / second * | 2–6oC / second * | 2–6oC / second * |
| Soak or preheat activation temperature | 100–180oC * | 100–180oC * | 140–220oC * |
| Soak or preheat activation time | 60–120 seconds * | 60–120 seconds * | 60–150 seconds * |
| Dwell time above liquidus | 60–90 seconds | 60–90 seconds | 60–90 seconds |
| Dwell time at peak temp. | 20 seconds max | 20 seconds min | 20 seconds max |
| * Verify with the supplier<br>** Coolest Temperature on the board | | | |



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# Time and Temp Profiles

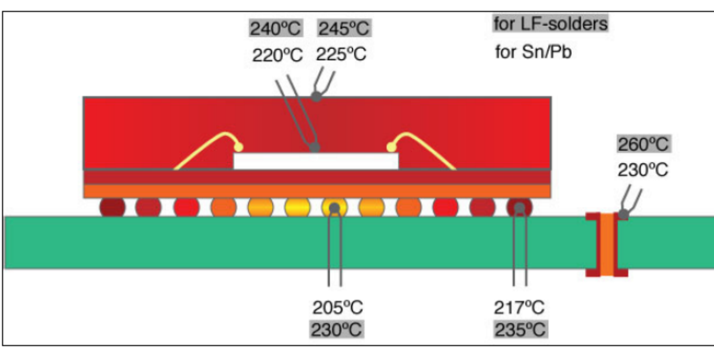



Figure 7-3 Examples of peak reflow temperatures at various locations at or near a BGA

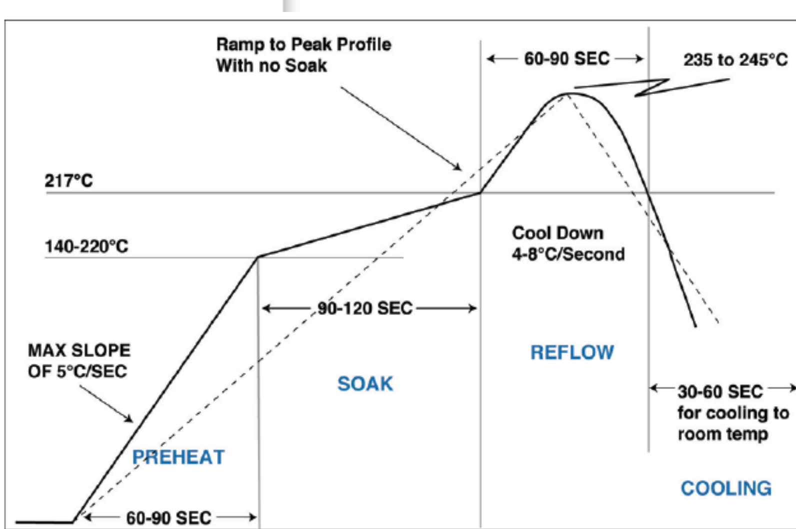
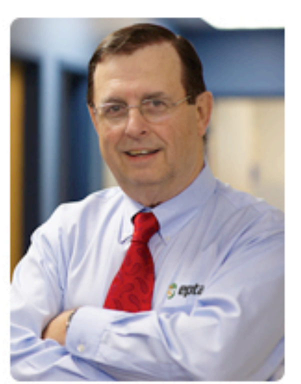



Figure 7-6 Schematic of reflow profile for lead-free assemblies

# Assembly of BGA to the PCB - Section 7



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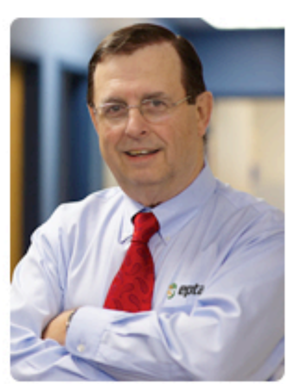
## Post SMT Process:

- Conformal coatings
- Underfills
- Corner adhesives
- Inspections
  - X-ray
  - Visual/Optical

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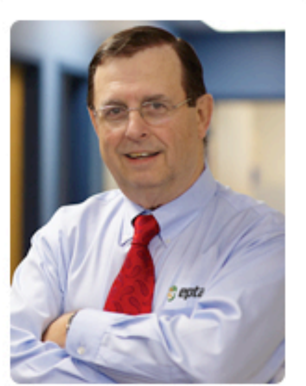
# Assembly of BGA to the PCB - Section 7

Rework and Repair

- Removal and Replacement
- Flux
- Paste
- Hot air system and profiles



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# Reliability and Defect Analysis

- Sections 8 discussed the application of the device and its reliability during its functional life.
- The basic thesis being the reliability of the solder joints when exposed to the operation life, thermal cycling and vibration cycling

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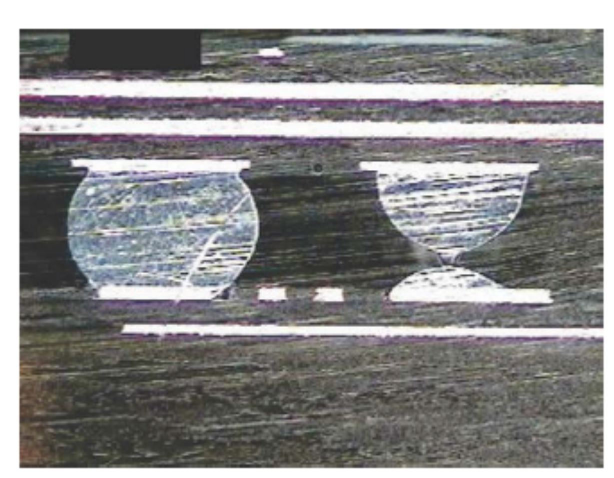
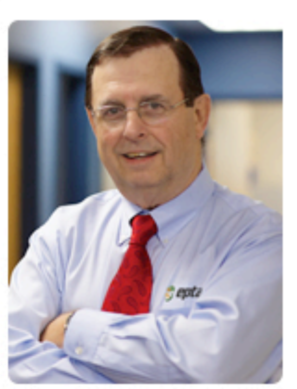
# Reliability and Defect Analysis

## Section 9, defect and failure analysis

### 9.3.2 Solder Joint Opens Due to Interposer Warp

|  | **Possible Cause**<br>- The failure appears to be due to insufficient paste release from the stencil or insufficient ball size.<br>- Warped package (smiling BGA) with corner balls lifted up<br><br>**Potential Solution**<br>- Check balls at incoming prior to assembly.<br>- Return package to supplier, Implement incoming inspection and or source audit,<br>- Apply extra solder paste on corner lands. |
|---|---|
| | |



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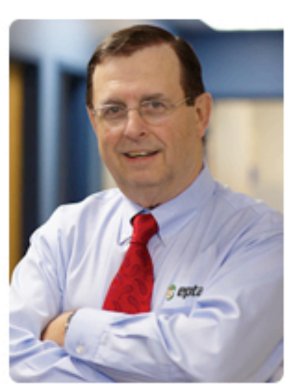
# Thank You

Questions?



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800-643-7822 ext 215

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