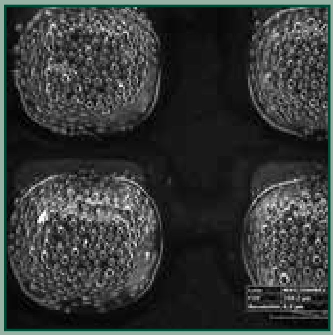
Indium8.9HF

Halogen-Free No-Clean Solder Paste for Use with Pb-Free Alloys

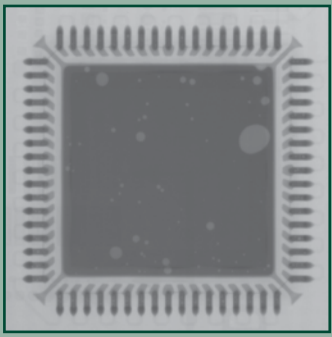
- Superior halogen-free reflow performance
- First-class printing performance
- Unique oxidation barrier eliminates common soldering defects
- Stable at room temperature and while printing



Paste Before Reflow

Head-in-Pillow

Graping



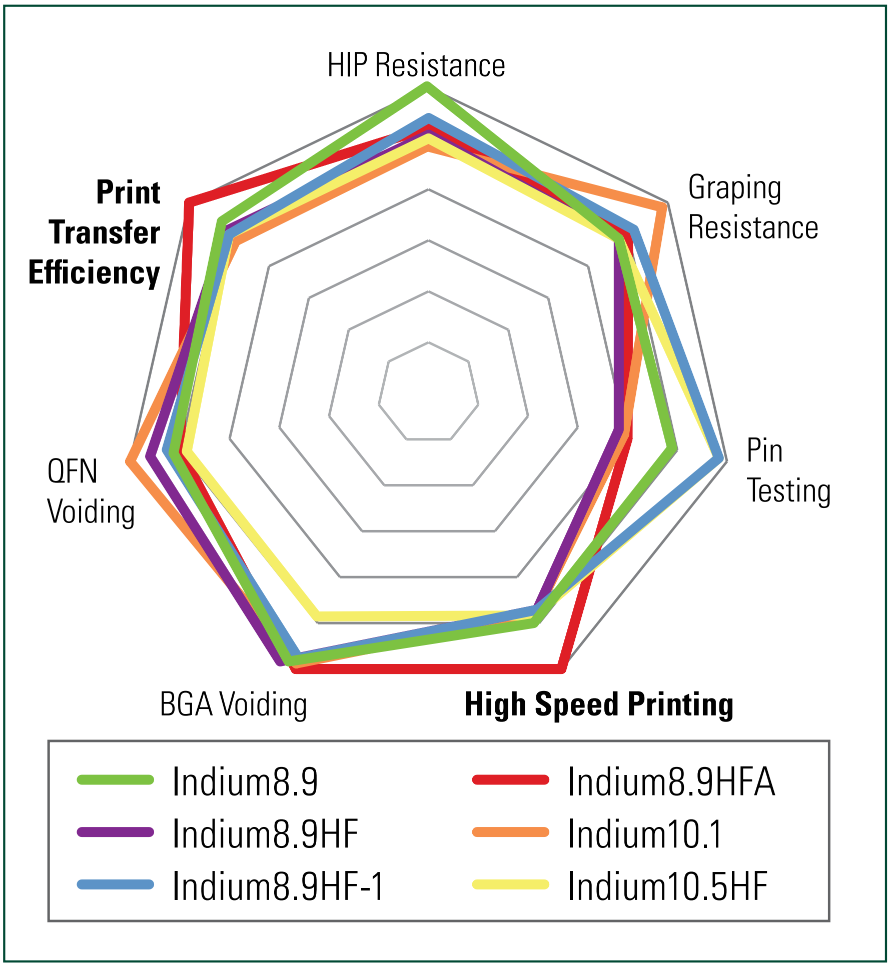
QFN Voiding

INDIUM CORPORATION®

From One Engineer To Another®

Pb-Free
SOLDER PASTE SERIES

Multi-faceted performance to bring the right balance of attributes, tailored to your process



Indium8.9HF Delivers:

- Low print pressures → Extended stencil life and reduced need for underside wipe
- Excellent transfer efficiency for small apertures → Extends process window
- Excellent resistance to bridging for fine-pitch components → Superior fine-pitch performance
- Quick recovery after pauses → Forgiving to increasing mix on lines and changeovers
- Halogen-free performance that rivals traditional solder paste → Environmental conformance
- Unique oxidation barrier to ensure robust reflow performance → Eliminates common defects
- Compatible with SnPb alloys → One flux for all your needs
- Low voiding
  – Very low QFN voiding with small powder sizes

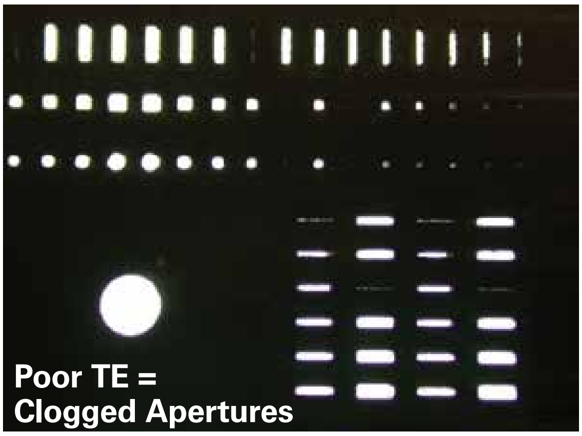
Pb-Free Alloys for Use with Indium8.9HF

Common Name	Composition	Solidus (°C)	Liquidus (°C)	Comments
SAC387	95.5Sn/3.8/0.7Cu	217	219	Original iNEMI recommended SAC alloy
SAC305	96.6Sn/3.0Ag/0.5Cu	217	220	Solder products value council recommended SAC alloy
SACm™	SnAgCu+Mn	217	225	Low-Ag alloy with enhanced performance compared to SAC305
SnAg	96.5Sn/3.5Ag	221E		

General Print Testing

- Printing was done on a test board using a DEK printer and Koh Young SPI unit
- 4 mil laser cut stencil
- Speeds from 50-250 mm/s were tested, 100 mm/s for response-to-pause testing
- Results are shown for solder mask defined square pads

$$\textbf{Transfer Efficiency} = \frac{\textit{Measured Solder Volume per Aperture}}{\textit{Theoretical Maximum Aperture Volume}}$$

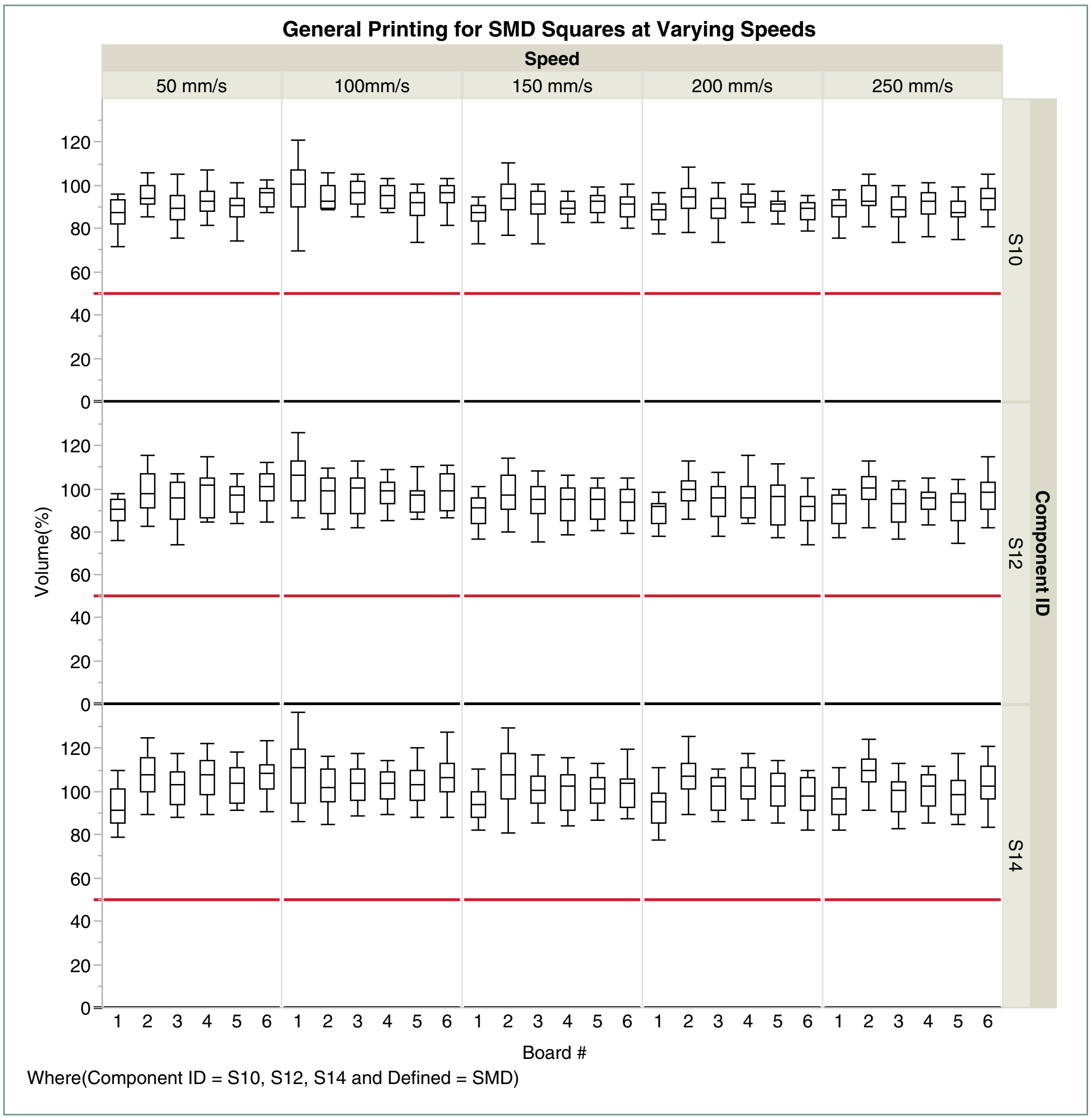


Test Results for Indium8.9HF (SAC305 Type 4 Powder):

- Data was analyzed for a variety of apertures and speeds to ensure reasonable variation for any possible print defects
- >80% initial transfer efficiency: **no need to discard first startup board**
- Transfer efficiencies stay **consistent, with no insufficients**

Benefits:

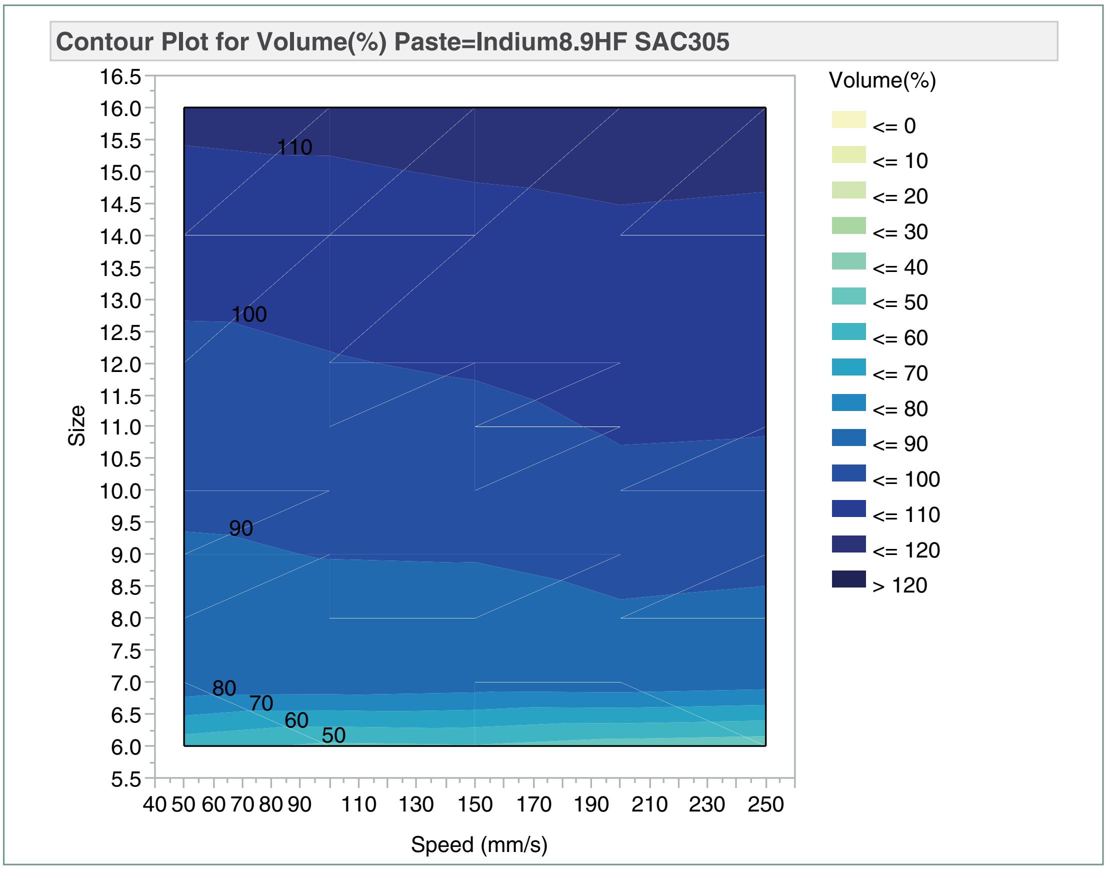
- Less frequent wiping can significantly decrease cycle time
- Overall, reduces the potential for process interruptions
- Robust printing process window to accommodate everyday process variation



Stencil Printing Speed and Aperture Sizes

Contour Plots:

- Show relationship between transfer efficiency and printing process
- For traditional materials, show transfer efficiency decreases with high print speeds or small apertures
- Clearly illustrate the process window for a material by highlighting its limitations



Aperture Ratio Chart (mils)							
Aperture Size (mils)	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Aperture Size (µm)	**254.00**	**279.40**	**304.80**	**330.20**	**355.60**	**381.00**	**406.40**
Stencil Thickness 4 mil	0.63	0.69	0.75	0.81	0.88	0.94	1.00

Marginal or attainable with newer generation products   Typically within process window

Test Results for Indium8.9HF:

- No insufficients for all aperture sizes and all speeds
- Most robust results, showing high quality printing for 10-16 mil apertures and 50-250 mm/s print speeds
- Wide process window will accommodate many designs and processes

Response-to-Pause Testing

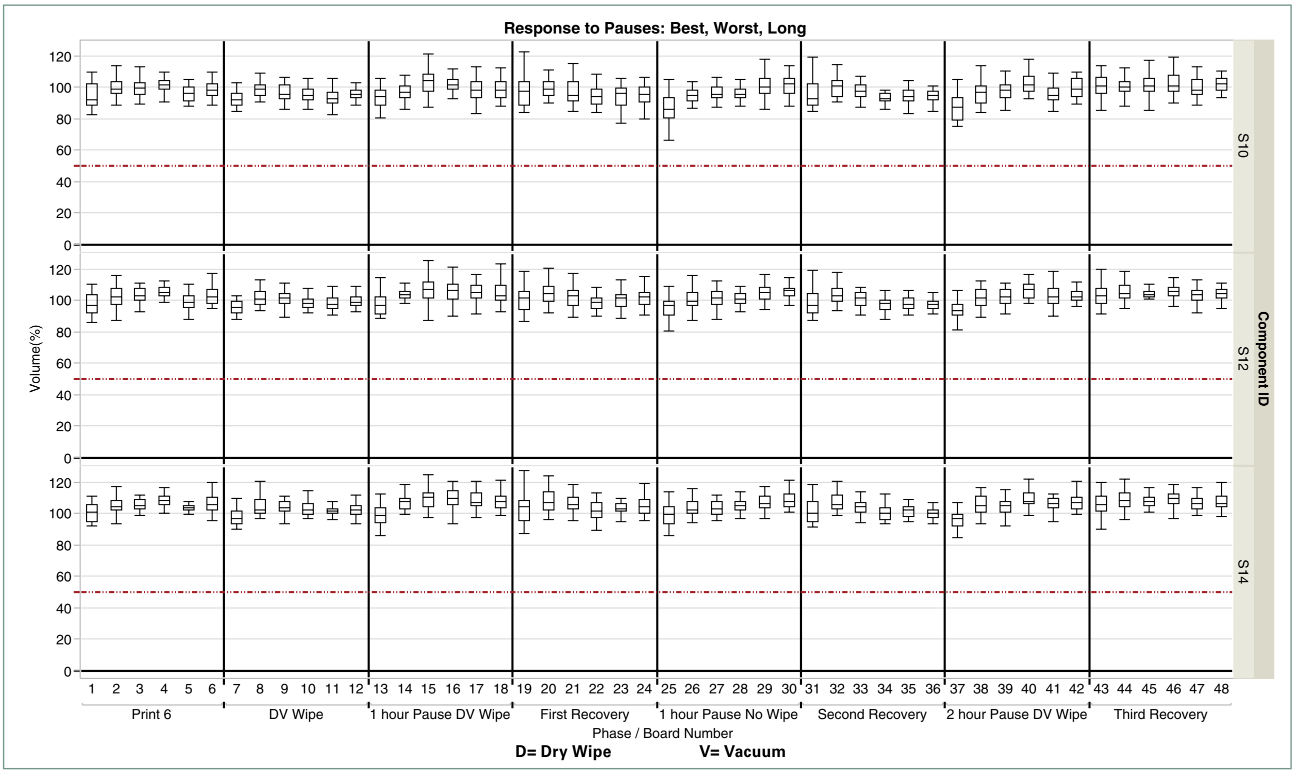
Why is response-to-pause important?

- Pauses and interruptions are common on SMT lines due to changeovers and maintenance
- Testing will show how much these pauses potentially change the printing process
- Procedure compares any drop in transfer efficiency for a pause to that of an under-stencil wipe cycle
- During testing, all apertures are monitored for changes in transfer efficiency

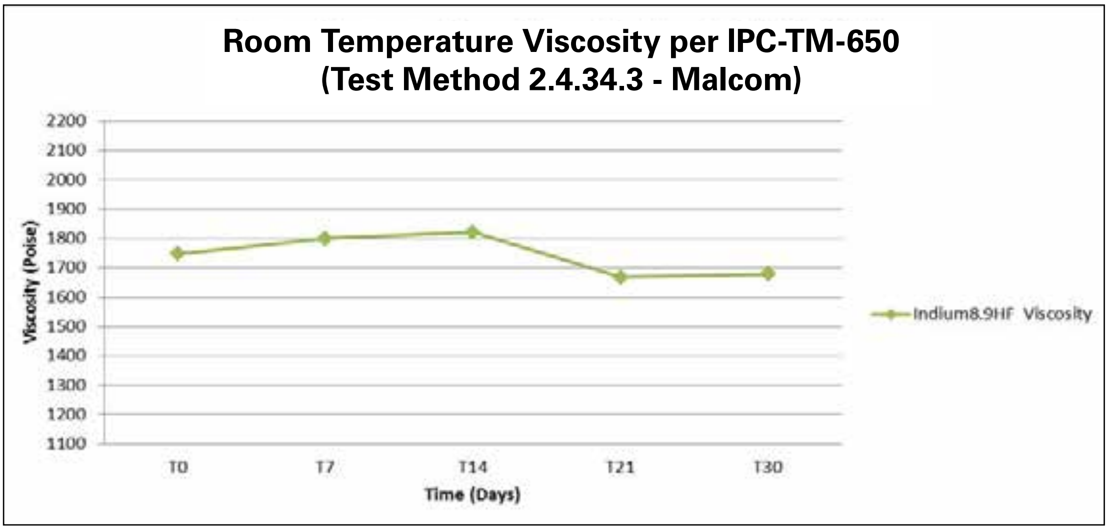
Note: It is best practice to always perform a wipe cycle before a pause!

Test Results for Indium8.9HF:

- No deposits (for all aperture sizes) with less than 50% transfer efficiency = no skips or insufficients (also no excessives more than 120%)
- 10, 12, 14 (square) with rounded corners
- Maintaining high quality transfer even after wipe or pause -> no need to wash or discard boards
- Builds confidence that interruptions will minimally impact process robustness



Viscosity per IPC-TM-650 (Test Method 2.4.34.3 – Malcom)



Viscosity variation <5%

- Time =0, 7, 14, 21, & 30 days @ 25˚C (±1˚C)
- Conditioned paste @ 30˚C prior to viscosity testing

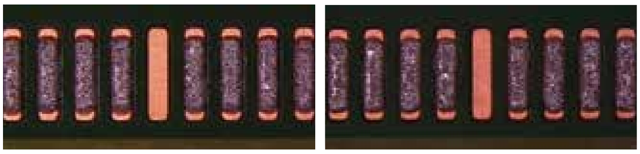
Slump Resistance

What causes hot slump and bridging?

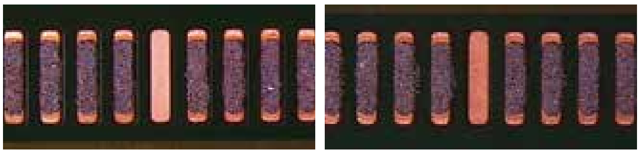
- Viscosity drops with increased temperature
- Solder deposits “slump” and risk connecting to adjacent deposits

Slump Resistance

- Tests the propensity of solder deposits to retain their shape and size over time after printing
- Prevents bridging and flux starvation



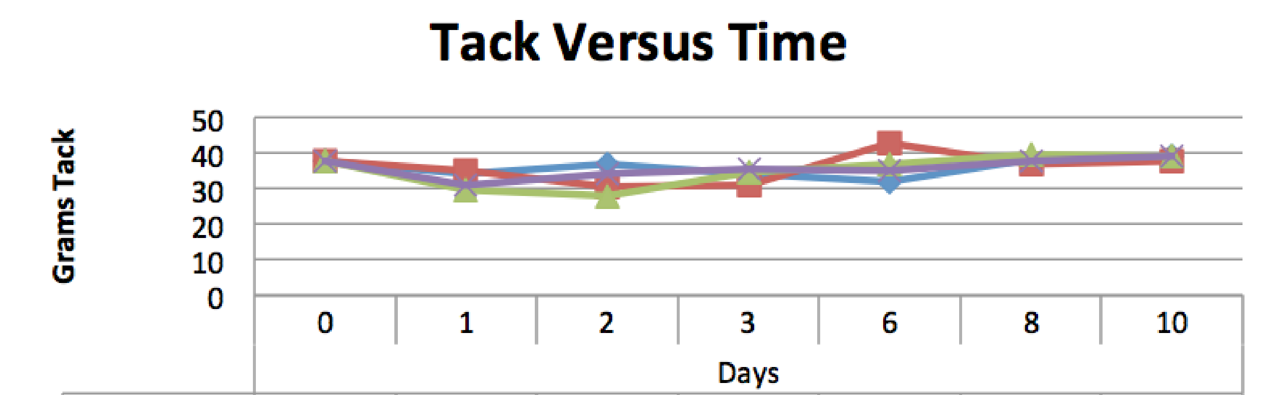
Before: Initial (room temperature immediately after printing)



After: After 15 min. at 150°C

Indium8.9HF Tackiness Test

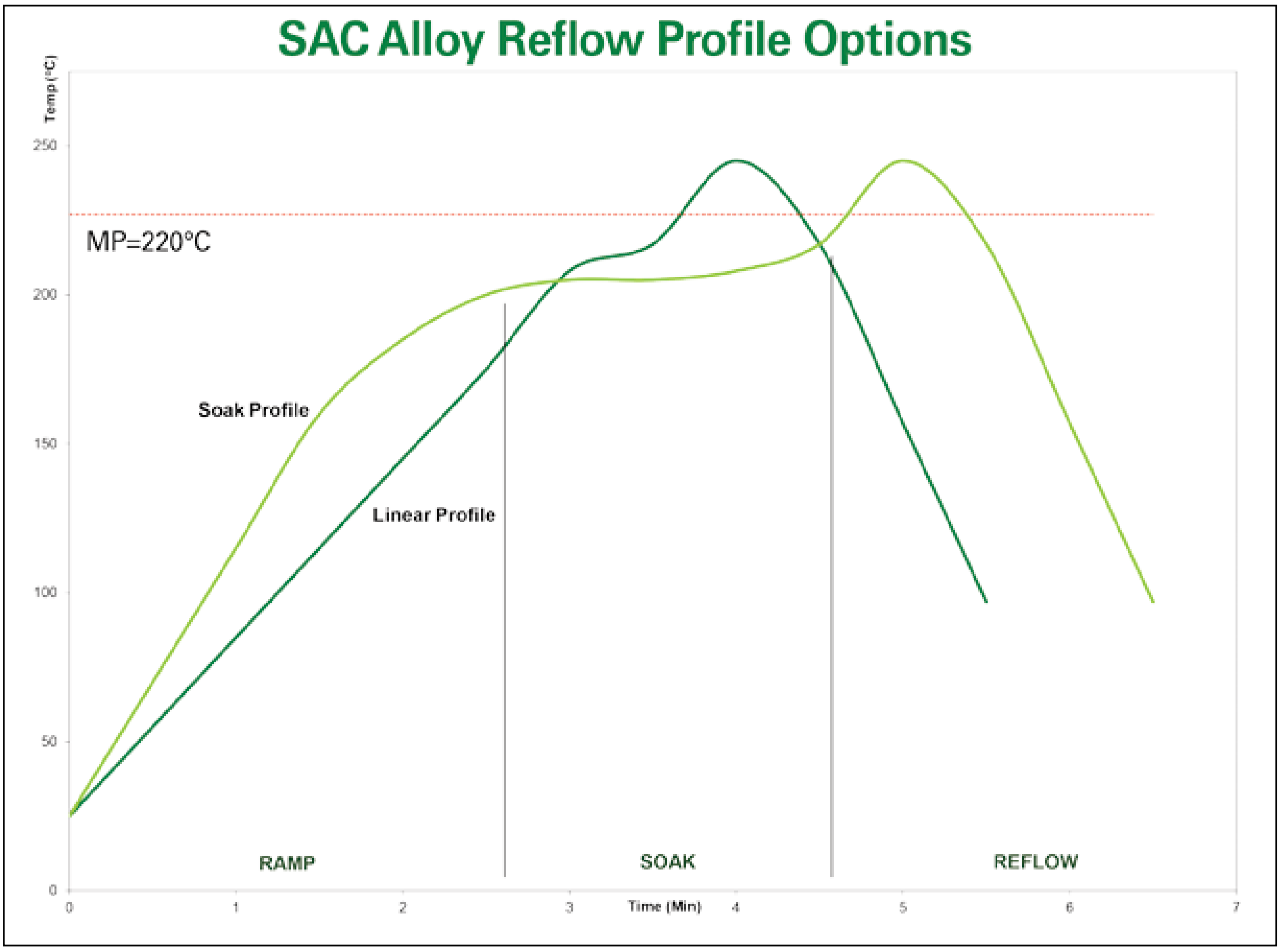
Tack vs. Time vs. Humidity



Days	0	1	2	3	6	8	10
20% RH	38	34	37	34	32	39	39
47% RH	38	35	31	31	43	37	38
65% RH	38	30	28	35	37	40	39
76% RH	38	31	34	36	35	38	39

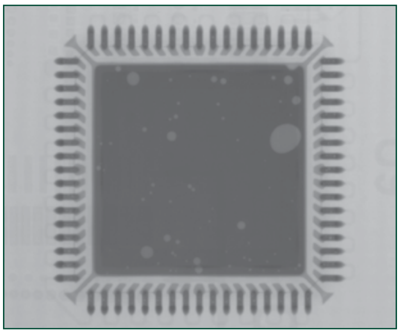
Optimizing Reflow

Note: Profiles are very dependent on the thermal mass of an assembly; these profiles are meant to be representative, using a test board.

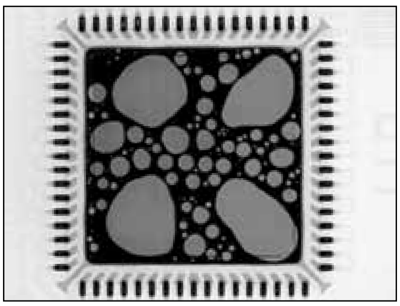


This profile applies to most Pb-free alloys in the SnAgCu (SAC) alloy system, including SAC305 (96.5Sn/3.0Ag/0.5Cu).

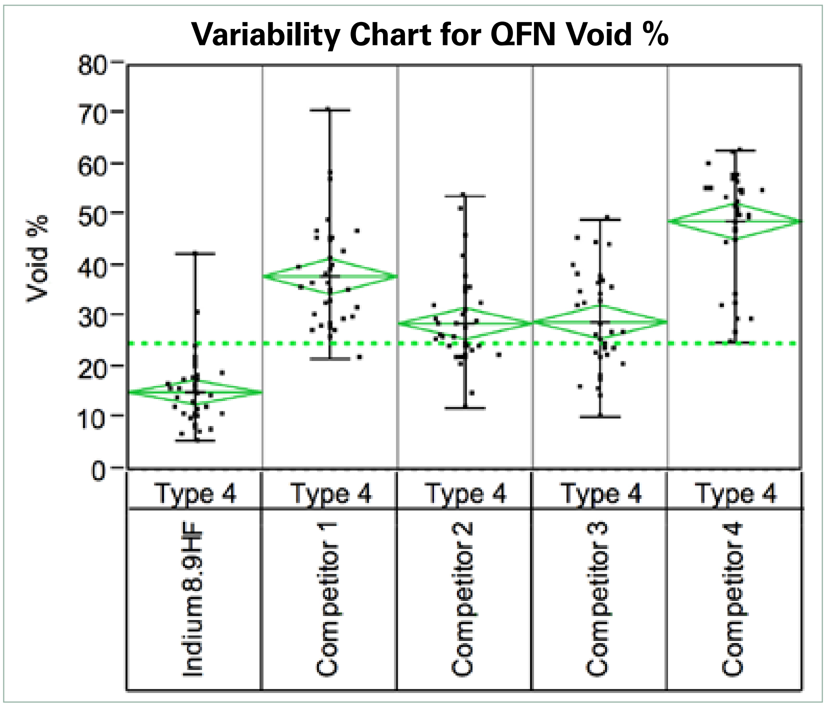
QFN Voiding



Indium8.9HF



Competitor 4



IPC/J-STD-004B Product Level Testing

Copper Mirror (Test #2.3.32)

Objective: The purpose of this test is to determine the corrosive (free-halide) properties of a flux.

Procedure: Flux is applied to a copper-coated glass slide and sits in a controlled environment for 24 hours. The flux is cleaned and the copper inspected for corrosion.

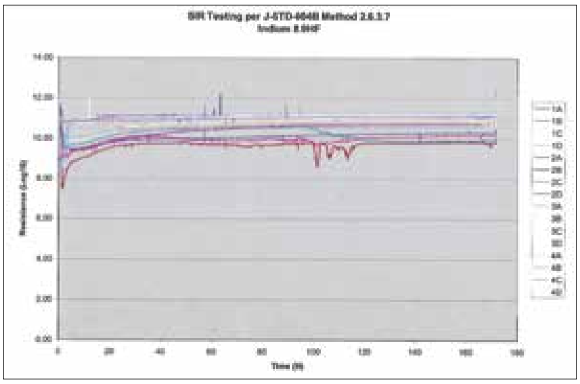
Results: Pass (No Color Change)

Surface Insulation Resistance (SIR) (Test #2.6.3.7)

Objective: The purpose of this test is to determine the surface insulation resistance (SIR) of the flux residue after paste reflow.

Procedure: Paste is stenciled onto the test board and reflowed. The uncleaned board is then sent to outside laboratory for testing.

Results: Pass



Oxygen Bomb with Ion Chromatography Halogen Testing (EN14582)

Objective: The purpose of this test is to isolate and quantify any halogen, ionic or covalently bonded, that is present in flux residues once assembly is complete.

Procedure: A sample is combusted in oxygen at very high temperatures, burning off any organic materials. The remaining ash will contain halogens and other inorganic substances that can be characterized by ion chromatography to determine the halogen content.

Results: Br <10 ppm
Cl <10 ppm

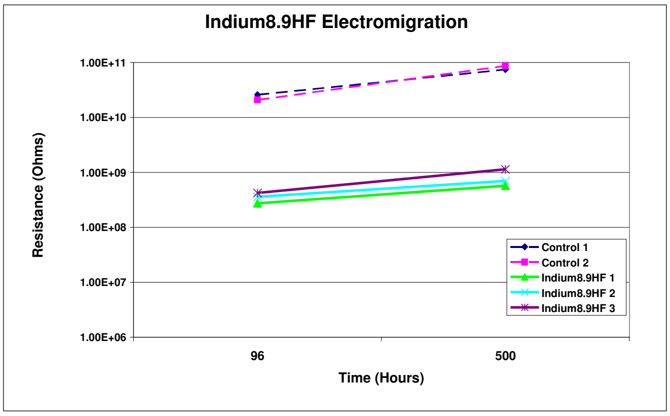
Below Detectable Limits

Electrochemical Migration (ECM) (Test #2.6.14.1)

Objective: The purpose of this test is to determine the electrochemical migration and SIR of the flux residue after paste reflow.

Procedure: Paste is stenciled onto the test board and reflowed. Uncleaned board is then sent to outside laboratory for testing.

Results: Pass

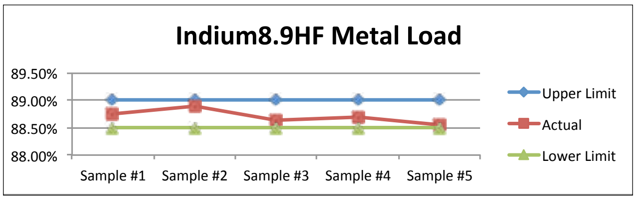


IPC/J-STD-005 Test Results

Metal Content (Test #2.2.20)

Objective: The purpose of this test is to determine the weight percent of metal in the solder paste. The percentage should not deviate more than +/- 1% from the solder paste specification.

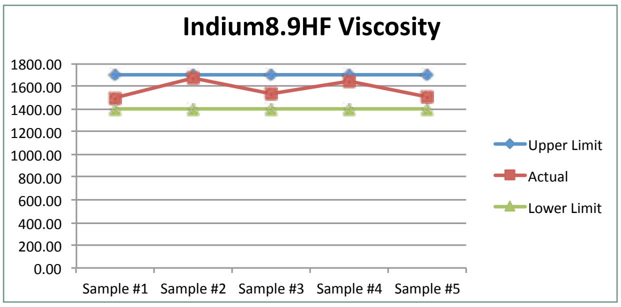
Procedure: A known weight of solder paste is reflowed in a glass beaker. A "button" of solder is formed from the coalescence of the solder. The "button" is cleaned and weighed. The ratio of "button" weight to original solder paste weight is the metal percent.



Viscosity (Test #2.4.34.2)

Objective: The purpose of this test is to determine the viscosity of a specific lot of solder paste. Viscosity testing is a fundamental test that ensures consistent performance from lot to lot.

Procedure: Approximately 500 g of solder paste is stabilized at 25 +/- 1°C and the viscosity is measured using a Malcom spiral pump viscometer at 5 rpms. The results are measured and compared to the nominal value. Solder paste lots with values outside the expected variation (USL and LSL) need to be investigated for possible performance related issues.



Wetting (Test #2.4.45)

Objective: The purpose of this test is to ensure that the solder paste has sufficient capability to wet to a copper substrate.

Procedure: Solder paste is printed onto a clean copper coupon and reflowed using the manufacturer's recommended reflow profile. The coupon is then inspected to ensure uniform wetting and no evidence of de-wetting or non-wetting.

Results and Image: Pass

Solder Ball (Test #2.4.43)

Objective: The purpose of this test is to validate soldering performance of a specific lot of solder paste. Solder ball testing is a fundamental test that ensures consistent performance for lot to lot.

Procedure: Three small deposits of solder paste are printed onto a ceramic coupon and reflowed at a temperature of approximately 240°C (for SnAgCu alloys). The coupon is then inspected to ensure complete coalescence of the solder paste, and that there are no extraneous solder balls in the flux pool. Results are compared to images in the J-STD-005 to determine whether it passes or fails.

Typical Result and Image: Pass, Preferred

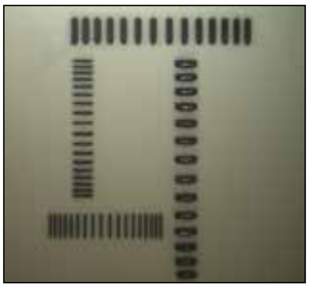
Slump (Test #2.4.35)

Objective: The purpose of this test is to determine the potential for slumping with a given solder paste.

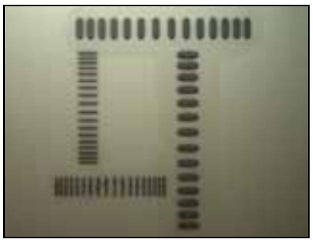
Procedure: For cold slump, solder paste is printed using an IPC-A-20 stencil on an alumina substrate and examined for maximum spacing bridged. Samples are stored at 47% relative humidity at room temperature (approx. 25 +/- 5°C) for 20 minutes. Samples are then re-examined for maximum spacing bridged. For hot slump, samples are again printed with an IPC-A-20 stencil on an alumina substrate and examined for maximum spacing bridged. Samples are then heated to 180°C for 15 minutes and allowed to cool. Samples are re-examined immediately, and again after 2 hours and 4 hours, for maximum spacing bridged.

Result: Pass Solder Paste Slump Test (IPC-TM-650 2.4.35)

Cold Slump



Hot Slump



Solder Printing Basics

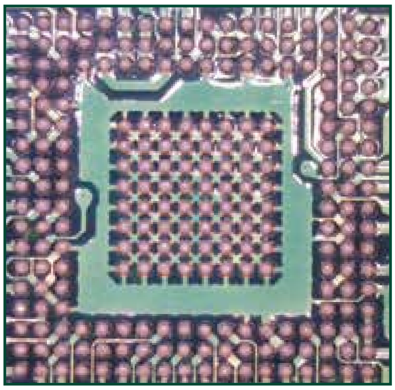
Best Practices for Solder Paste Storage and Handling

1. Paste is packaged for overnight shipping and should arrive at room temperature (<25°C).
2. Upon arrival, remove paste containers from cooler and store in <10°C.
3. Solder paste should be allowed to reach ambient working temperature prior to use. Generally, paste should be removed from refrigeration at least two hours before use. Actual time to reach thermal equalibrium will vary with container size. Paste temperature should be verified before use. Jars and cartridges should be labeled with date and time of opening.

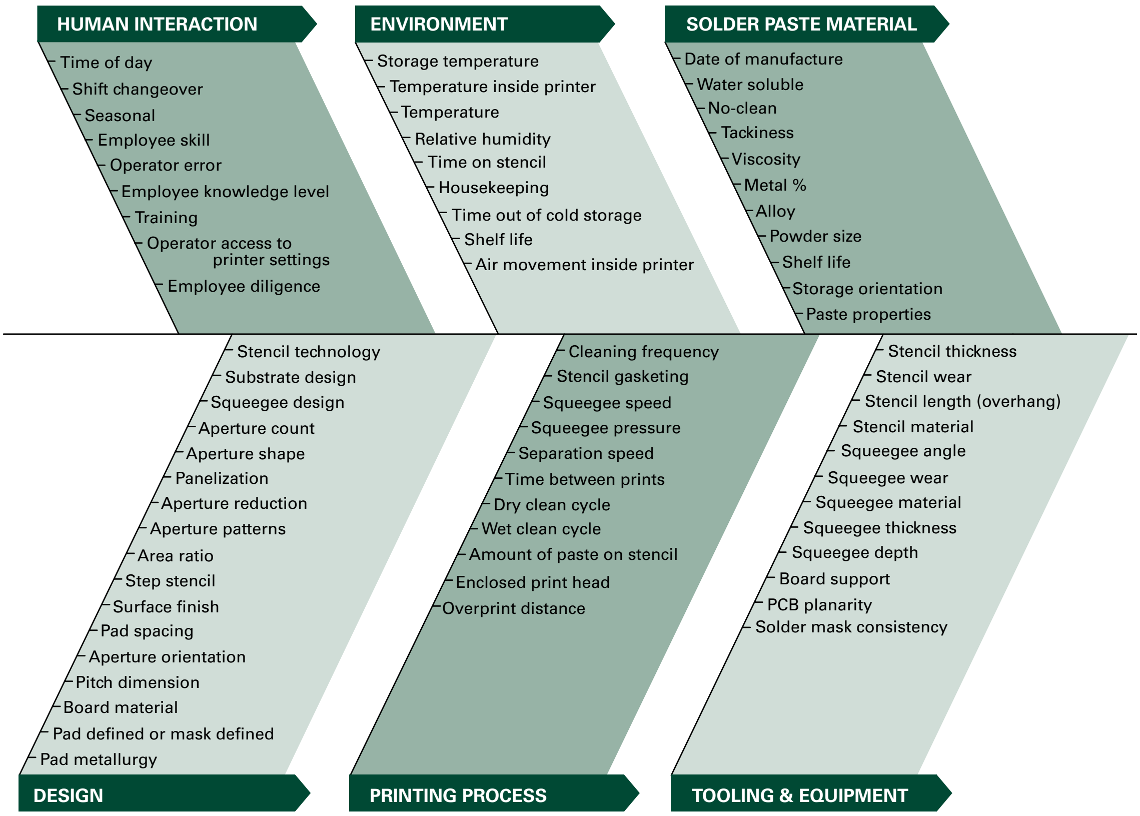
Note: Paste containers opened while still cold can absorb water from condensation, affecting the integrity of the paste; likewise, exposing paste to temperatures above 25°C can cause degradation.

Measurable Attributes of Good Paste Performance and Print Quality

- Transfer efficiency
  - Small apertures
  - Varying shapes and area ratios
  - Fine pitch
- Response-to-Pause
  - Print speed variation
- Slump
  - Under hot and cold conditions
- Reflow performance
  - Oxidation resistance



Factors that Cause Variation in Transfer Efficiency



Stencil Printing Process

Stencil Design:

Electroformed and laser cut/electropolished stencils produce the best printing characteristics among stencil types. Stencil aperture design is a crucial step in optimizing the print process. The following are a few general recommendations:

- Discrete components — A 10-20% reduction of stencil aperture has significantly reduced or eliminated the occurrence of mid-chip solder beads. The “home plate” design is a common method for achieving this reduction.
- Fine pitch components — A surface area reduction is recommended for apertures of 20 mil pitch and finer. This reduction will help minimize solder balling and bridging that can lead to electrical shorts. The amount of reduction necessary is process dependent (5-15% is common).
- For optimum transfer efficiency and release of the solder paste from the stencil apertures, industry standard aperture and aspect ratios should be adhered to.

Stencil Printing Best Practices

- Board support, typically provided by vacuum tooling, is of paramount importance for consistent stencil printing.
- Use enough paste so that a generous bead is able to roll freely when the squeegee moves freely (typically 1/3” to 3/4” in diameter).
- Set squeegee pressure just high enough to ensure a clean swipe of the squeegee with no paste left on the stencil after the pass (for indium pastes, typically 5 kg is sufficient for a 10” blade).
- Solder paste is a thixotropic material, meaning it thins under pressure, so it only reaches optimal performance after a couple of prints (number varies depending on paste).
- Proper gasketing is very important, meaning alignment of apertures with pads, levelness of board surface, and solder mask definition should not detract from contact between the surface of the board and the stencil.
- To check for proper gasketing, check the alignment of stencil and board. While in contact, tap the stencil to ensure there is no space for deflection.
- Wiping the underside of the stencil intermittently to remove any excess paste is often necessary. Typically, a dry wipe with advancing paper and a vac cycle is sufficient.
- Refer to the product data sheet for specific wipe frequency recommendations. Frequency is also highly dependent on proper gasketing and process optimization.
- Calculating area ratios and staying within typical stencil guidelines will give best first-pass yields (refer to the table below for guidelines).
- Powder size choice can also affect stencil printing (refer to Powder Choice application note for more information).
- Typically, higher transfer efficiencies correlate to higher area ratios.

Calculating Area Ratios

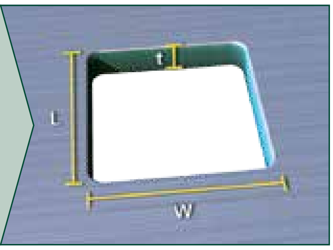
Area Ratio For Square/ Rectangular Apertures

$$\text{Area Ratio} = \frac{\text{Area Opening}}{\text{Area Walls}}$$

$$\text{Area Opening} = L \times W$$

$$\text{Area Walls} = 2t(L + W)$$

$$\text{Area Ratio} = \frac{L \times W}{2t(L + W)}$$



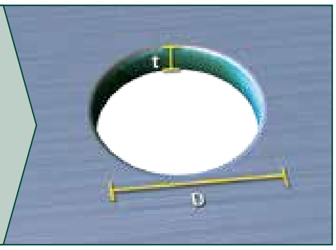
Area Ratio For Circular Apertures

$$\text{Area Ratio} = \frac{\text{Area Opening}}{\text{Area Walls}}$$

$$\text{Area Opening} = \frac{\pi D^2}{4}$$

$$\text{Area Walls} = \pi D t$$

$$\text{Area Ratio} = \frac{D}{4t}$$



Metric Aperture Ratio Chart (microns)

		50	100	150	160	170	180	190	200	250	300	350	400
Aperture Size (μm)		**50**	**100**	**150**	**160**	**170**	**180**	**190**	**200**	**250**	**300**	**350**	**400**
Aperture Size (mils)		**1.97**	**3.94**	**5.91**	**6.30**	**6.69**	**7.09**	**7.48**	**7.87**	**9.84**	**11.81**	**13.78**	**15.75**
Stencil Thickness (mils)	5	0.10	0.20	0.30	0.31	0.33	0.35	0.37	0.39	0.49	0.59	0.69	0.79
	4	0.12	0.25	0.37	0.39	0.42	0.44	0.47	0.49	0.62	0.74	0.86	0.98
	3	0.16	0.33	0.49	0.52	0.56	0.59	0.62	0.66	0.82	0.98	1.15	1.31

Not typically within the process window Marginal or attainable with newer generation products Typically within process window

Defect Elimination: Graping

Oxidation barrier technology, which helps with HIP, also prevents graping on small paste deposits.

Graping happens because:

- Small paste deposits with fine solder particles have a much lower ratio of flux-to-surface area of oxide
- High reflow temperatures and long soak profiles promote more oxidation
- Flux spreading can leave some areas starved for flux
- Oxide is not cleaned from the surface; particles fail to coalesce properly

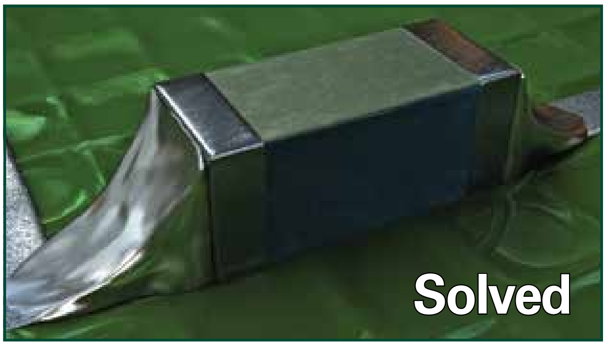
Be careful – graping is often misdiagnosed as cold solder.

Solutions:

- Better oxidation suppression
- Less flux spreading
- Optimized reflow profile

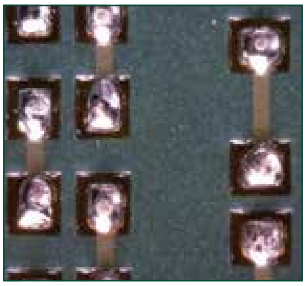
Additional Approaches to Eliminate Graping:

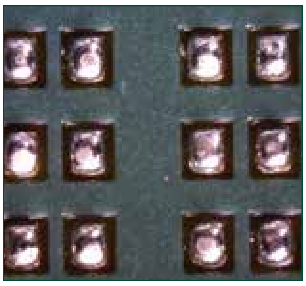
- Maximize aperture dimensions within known stencil design rules to ensure the maximum deposited paste volume
- Optimize aperture profile to enable maximum paste release (e.g., trapezoid aperture)
- Set the highest possible separation speed to maximize paste release
- Consider changes to reflow profile to minimize soak time

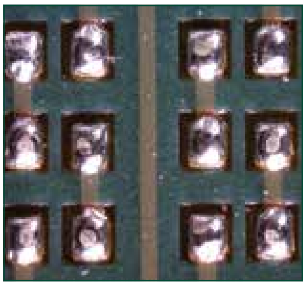


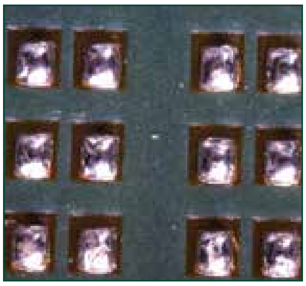
Causes of Graping

Reflow	Printing	Materials	Processes
Ramp rate	Stencil thickness	Solder paste oxidation resistance	Contaminated incoming air
Soak time	Aperture size	Powder size	Time between print and reflow
Peak temperature	Transfer efficiency	PCB surface finish and solderability	Aperture clogging
Air flow rate in reflow oven		Component finish and solderability	Paste time on stencil
			Poor paste handling or storage









Defect Elimination: Head-in-Pillow

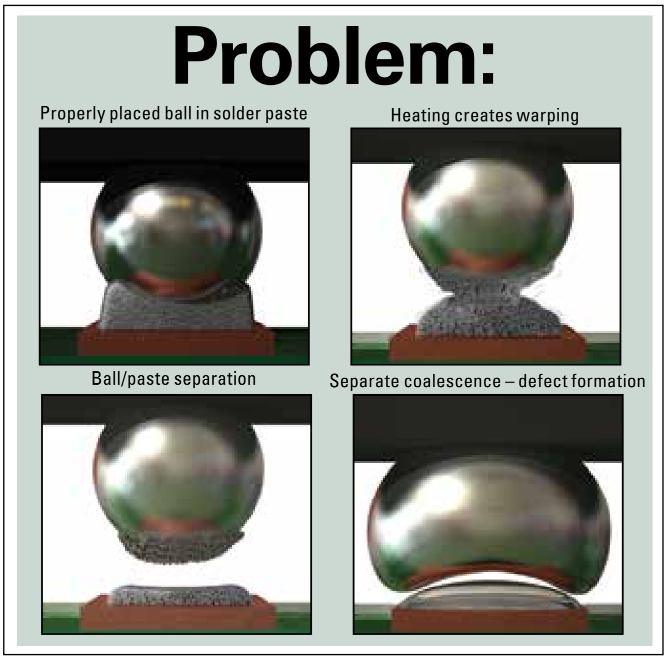
How does it happen?

1. Component warps during preheat and soak profile
2. Paste and ball separate prior to melting
3. Paste and ball melt separately and solidify separately
4. Oxide layer forms on surface of molten solder
5. Component warps back during cool down but has already solidified, or oxide layer is too thick for paste and ball to coalesce

How Indium8.9HF Eliminates Head-in-Pillow

- High flux activity and oxidation barrier
- Excellent transfer efficiency with extremely low variability
- Slump resistance/over-print capable
- High tackiness

Head-in-Pillow Defect Formation



Solutions for QFN Voiding

How Indium8.9HF Reduces Voiding Under QFNs:

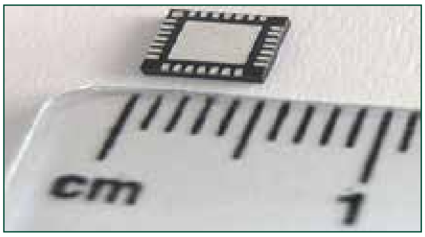
- Reduces size of single largest void and fewer total voids
- Increased activity effectively removes oxide from small solder particles
- Optimized composition of volatile flux components cleans surfaces, while reducing gas entrapment
- Wide processing window allows for reflow optimization to further enhance low voiding performance

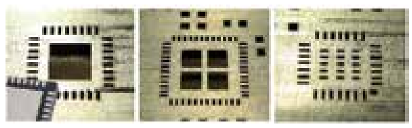
Reduce QFN Voiding Through Stencil Design

Instead of printing one large square at the center of QFNs:

- With greater paste volume, voiding increases, so aperture designs that limit paste volume will reduce voiding
- Break up this square into smaller apertures
- Spaces between printed areas leave paths for volatiles to escape
- Larger aperture separations will further reduce voiding

For additional information, refer to paper: *"Influence of Reflow Profile and Pb-Free Solder Paste in Minimizing Voids for QFN Assembly"* by T. Jensen, E. Briggs, et al.





Modified stencil design for thermal pad

Further Minimizing QFN Voiding Using Solder Preforms

Using a square solder preform with paste adds the solder volume needed without adding additional volatiles, which will contribute to voiding underneath the QFN. Crucial considerations for this method:

- Stencil design
- Preform geometry
- Placement parameters (in respect to thermal pad)
- Preform flux coating
- Reflow profile

For additional information, refer to paper: *"Minimizing Voiding in QFN Packages Using Solder Preforms"* by S. Homer and R. Lasky, PhD, PE, or **askus@indium.com** for technical assistance on implementing this method.

Featured Pb-Free Alloys

Choosing an Alloy

1. Final assembly operating conditions (temperature and stresses):
   - To eliminate thermal failure (melting of joint), the alloy softening point (solidus) should be 40°– 50°C above operating temperature.
   - Mechanical stresses induced by temperature fluctuations must be matched by alloy compliance (thermal fatigue resistance).
   - Hostile environments, such as salt or swamp conditions, may require corrosion-resistant alloys.
2. Surface metallization (alloy compatibility):
   - The alloy must wet to surfaces while not scavenging (dissolving) excessive surface metal or forming brittle intermetallics.
   - Typical surface metal is gold (Au) over nickel (Ni). Recommended gold thickness is generally between 8–15 micro inches (2,000–4,000 angstroms). If Au thickness is greater than 8–15 micro inches, a non Sn-bearing alloy may be needed to avoid brittle AuSn intermetallics.
3. Assembly conditions and methods:
   - Most alloys will form a solder joint best at temperatures 20°– 40°C above the alloy's liquidus point. Consequently, the peak temperature limitations of components must be considered.
   - Heating methods could impact the alloy choice. For example, a fluxless process with no reducing atmosphere may require an alloy that has low oxide formation, such as 80Au/20Sn.
4. Fabrication capabilities:
   - All alloys cannot be formed into all shapes and sizes. For example, 58Bi/42Sn is an excellent low temperature alloy, but its brittle nature makes the formation of fine wire difficult.
   - Key variables that impact fabrication: brittleness (low malleability and ductility); oxide formation rate; melting temperature; segregation; and softness.
5. Cost:
   - Alloy elemental composition can be an issue. For instance Au, Ag, and In alloys can be expensive.
   - Costs will vary due to fabrication difficulties and the quantity ordered.

Pb-Free Alloys for Solder Paste

Common Name	Composition	Solidus (°C)	Liquidus (°C)	Comments
InSn	52.0In/48.0Sn	118 (eutectic)		Lowest melting point practical solder
Indalloy227	77.2Sn/20.0In/2.8Ag	175	187	Not for use over 100°C due to 118°C SnIn eutectic
SnInCe	87.0Sn/13.0In+Ce	190	205	Best-in-class thermal cycling performance due to high ductility; addresses high CTE mismatches
Indalloy254	86.9Sn/10In/3.1Ag	204	205	No SnIn eutectic problems; potential uses for flip-chip assembly
SnBiAg	91.8Sn/4.8Bi/3.4Ag	211	213	Board and component metallizations must be Pb-free
SAC405	95.5Sn/4.0Ag/0.5Cu	217	218	Petzow (German) prior art reference makes this alloy patent-free
SAC387	96.5Sn/3.8/0.7Cu	217	219	Original iNEMI recommended SAC alloy
SAC305	96.6Sn/3.0Ag/0.5Cu	217	220	Recommended SAC alloy by the Solder Products Value Council
SAC105	98.5Sn/1.0Ag/0.5Cu	217	225	Low-cost alloy with reasonable drop test performance
SACm™	Sn/Ag/Cu+Mn	217	225	Drop test performance as good as SnPb
SAC0307	99.0Sn/0.3Ag/0.7Cu	217	227	Low-cost SAC alloy
SnCu	99.3Sn/0.7Cu	227 (eutectic)		Inexpensive; possible use in wave soldering
Sn992	99.2Sn/0.5Cu+Bi+Co	227		High-performance and low-cost solder alloy
"J" alloy	65.0Sn/25.0Ag/10.0Sb	223 (eutectic)		Die-attach solder alloy; very brittle
Indalloy133	95.0Sn/5.0Sb	235	240	High-temperature Pb-free alloy
Indalloy259	90.0Sn/10.0Sb	250	272	High-temperature Pb-free alloy

Indium Corporation offers hundreds of other alloy choices. Visit our website at www.indium.com/solder-alloy-guide for more information.

Sn992

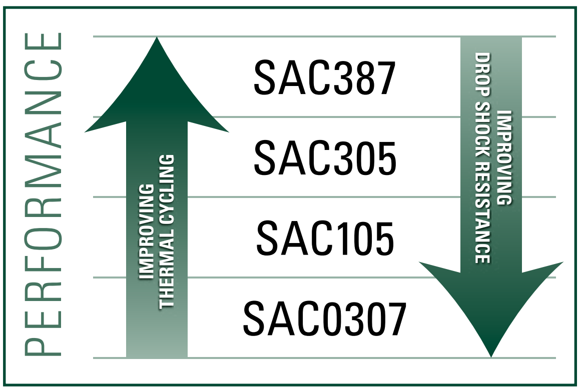
Low-cost, Pb-free

- Performance and appearance comparable to SAC305
- No Ag for future cost stability
- Cobalt enhances wetting and shininess

SACm™

Low-Ag, High-performance

- Enhanced reliability compared to traditional SAC alloys
- Doped with manganese to strengthen thermal reliability
- High resistance to drop shock



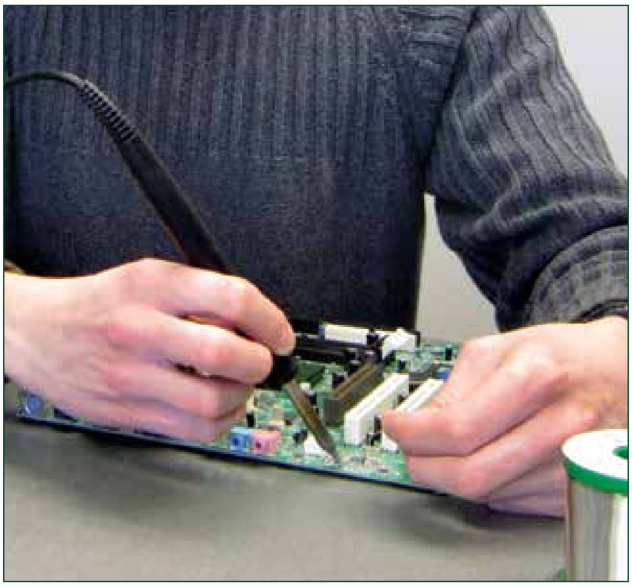
Technical Support

From One Engineer To Another®

Indium Corporation's research scientists, application engineers, and technical support engineers work closely with our customers to develop custom solutions to their technical problems and optimize their processes.

Indium Corporation's PhD scientists and engineers are certified by many of the top industry organizations, including the SMTA and the IPC. In addition, our Six Sigma Green Belt- and Black Belt-certified staff are trained in advanced process management methods to help you to:

- Increase yields
- Improve customer satisfaction
- Increase revenues
- Reduce defects
- Increase profits
- Deliver high value and return on investment



Questions? Go to *Contact Us* on www.indium.com

Locations Worldwide

- Electronics Assembly Materials
- Engineered Solders & Alloys
- Metals & Compounds
- Metal Thermal Interface Materials
- Nanotechnology
- Semiconductor Assembly Materials
- Solar Energy Materials

Our Goal

Increase our customers' productivity and profitability through premium design, application, and service using advanced materials.

Our basis for success:

- *Excellent product quality and performance*
- *Technical and customer service*
- *Cutting-edge material research and development*
- *Extensive product range*
- *Lowest cost of ownership*

ISO 9001 REGISTERED

Form No. 99203 (A4) R0

www.indium.com **europe@indium.com**

ASIA: Singapore, Cheongju, Malaysia: +65 6268 8678
CHINA: Suzhou, Shenzhen: +86 (0)512 628 34900
EUROPE: Milton Keynes, Torino: +44 (0) 1908 580400
USA: Utica, Clinton, Chicago, Rome: +1 315 853 4900

INDIUM CORPORATION®