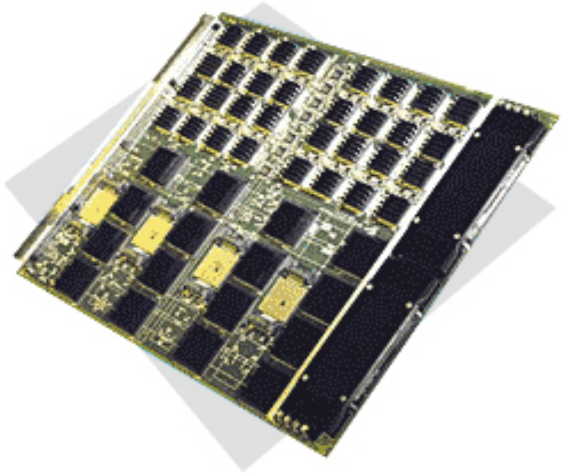
SnCu Based Alloy Design for Lower Copper Dissolution and Better Process Control



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Material Concepts for Alternative Alloys

To meet the market demand for a best-in-class, low-cost lead-free alloy for wave, selective and dip soldering

- SAC305 is the industry standard but higher in cost due to Silver content
- New material had to have the following attributes:
  - Low cost, Silver free
  - Low drossing, low oxide potential
  - Shiny joints without shrink holes
  - Minimized dissolution of Copper and other metals
  - Low solder maintenance
  - Good wetting behavior on popular lead-free finishes

SAC305 Lead-Free Alloy

Industry standard lead-free alloy for SMT, wave, rework

3% Silver → High Cost

Benefits:

- Mass Production – Industry Standard alloy
- Prevalence of Reliability Data
- Lower Melting Temperature than SnCu systems
- Increased Wetting Speed vs. SnCu systems (temperature dependent)
- Perceived compatible in reflow soldering using SAC

SAC305 Lead-Free Alloy

Concerns:

- Cost (3% Ag may add $6/pound to metals cost)
- High Rate of Copper Dissolution
- Dull or Matte Finish Solder Joints
- Hot Tear / Shrink Hole Defects

- Industry needs new materials to resolve these issues

Alloy Cost Comparative and new alloy design

Alloy	Composition	Relative Cost (approx)
Sn63	Sn63Pb37	1x
K100*LD*	Sn99.3Cu0.7 + Ni + Bi	1.5x
SAC305	Sn96.5Ag3.0Cu0.5	3x

Addition of bismuth and other elements in lead-free solders

Bismuth can be added in small amounts to certain lead-free solder alloy compositions to improve the wetting ability and slightly reduce the melting temperature of the solder. As much as 1% bismuth is soluble in solid tin. The much lower surface tension of bismuth compared to tin helps wetting.

- **Bismuth acts synergistically with Nickel to reduce copper dissolution further than nickel alone.**
- **Bismuth reduces surface tension of the SnCuNi alloy.**
- **Addition of phosphorus less than 0.010% reduces oxidation, usual practice.**

Lower costs

K100*LD* - reduced costs for wave and selective systems

- Silver-free alloy is ~50% less in metals cost vs. SAC305
- Low Dissolution of Copper means lower pot maintenance and fewer defects
- Shiny joints means minimal operator training and AOI recalibration costs
- Minimal dross means lower maintenance & dross-handling costs

Typically seen with SAC solders in wave, selective and hand-soldering

5 Soldering

5.2.11 Soldering Anomalies – Hot Tear/Shrink Hole

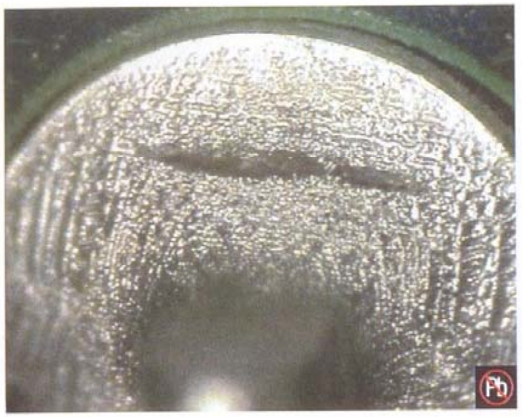


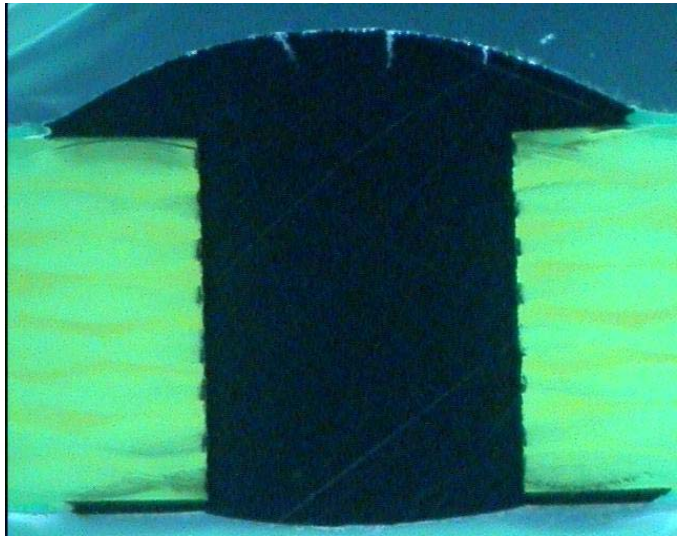
Figure 5-67

Acceptable - Class 1,2,3

- For connections made with lead free alloys:
  - The bottom of the tear is visible.
  - The tear or shrink hole does not contact the lead, land or barrel wall.

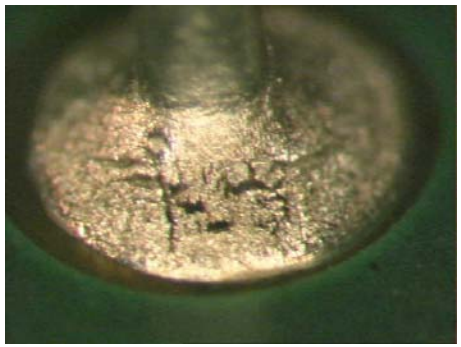
Defect - Class 1,2,3

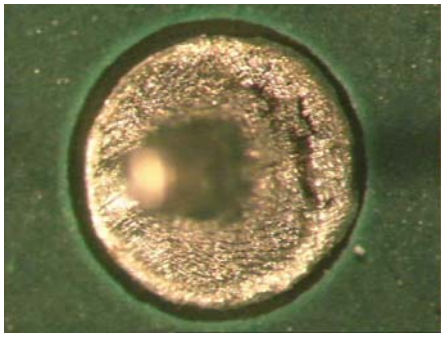
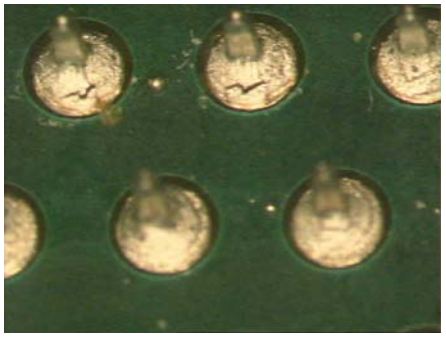
- Shrink holes or hot tear in connections made with SnPb solder alloys:
- For connections made with lead free alloys:
  - The bottom of the shrink hole or hot tear is not visible.
  - The tear or shrink hole contacts the lead or land.



SAC shrinkage on a wave joint

Many assemblers are concerned about hot tear inspection and long term effects.



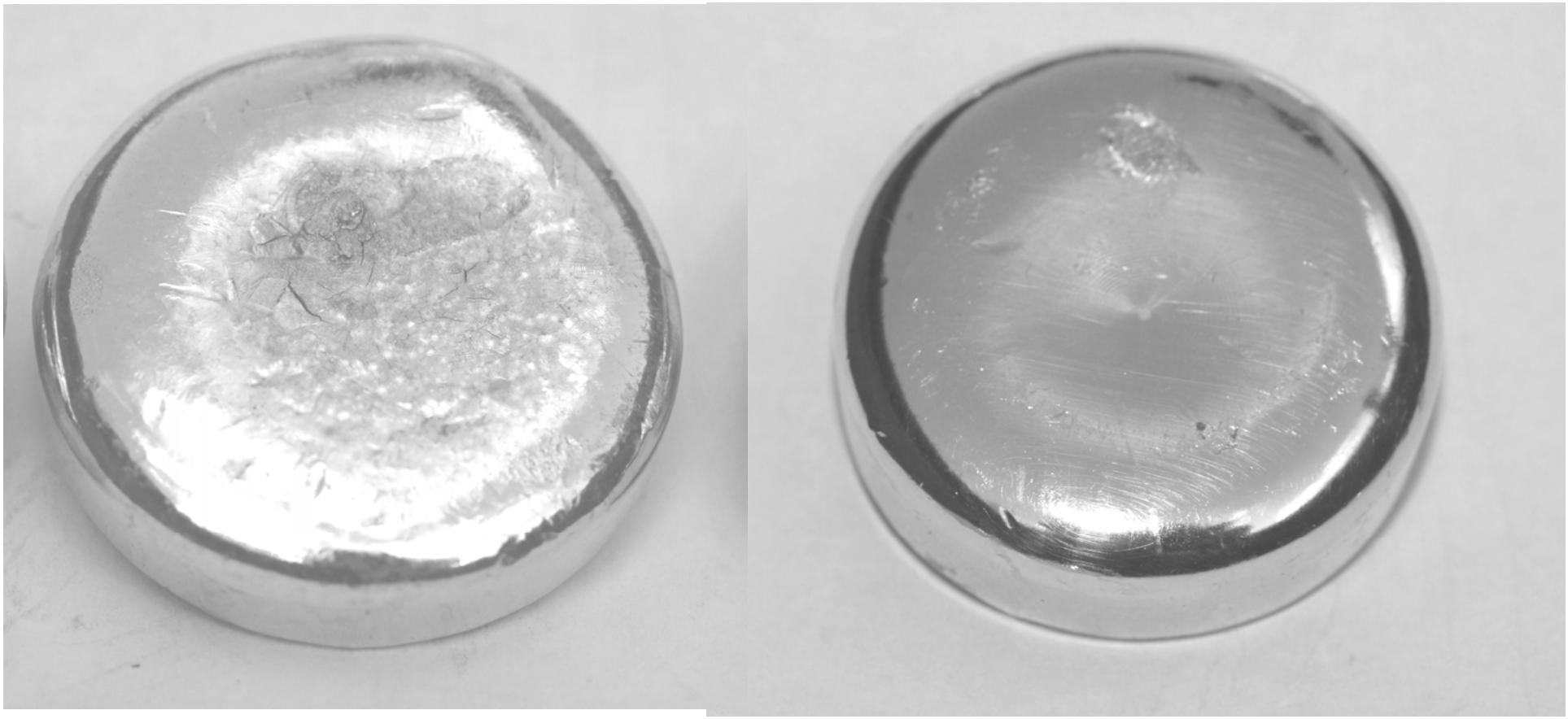



SAC after 500 thermal cycles, photographs iNemi Lead-free Wave Project 2006, initial work.

Surface Cosmetics

SAC

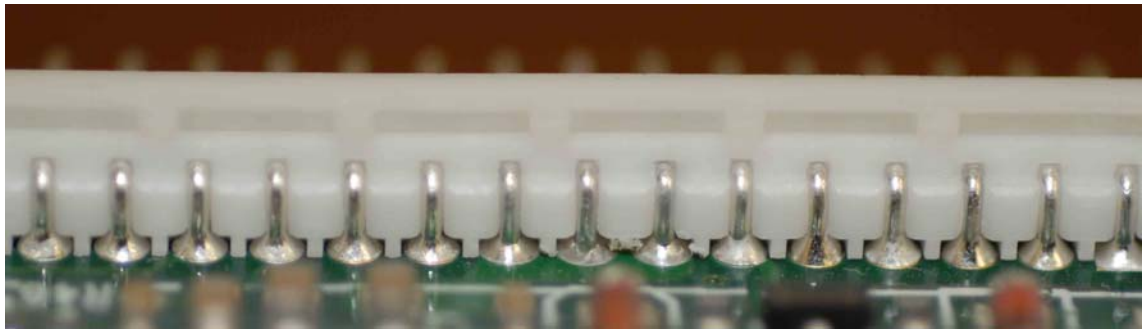
SnCuNi+Bi

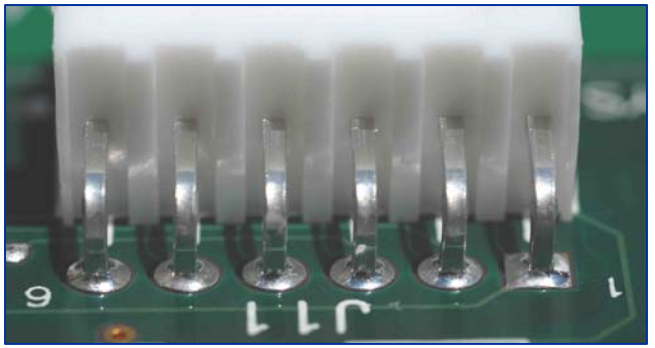


Alloy properties summary

	K100*LD*	SAC305
Melt Point	~227C	217-220C
Pasty Range	0	3C
Appearance	Shiny	Dull
Shrink Holes	No	Yes
Copper Dissolution (Sn63 = 1)	0.8	2.1
Pot Management	Easiest	Difficult
Reactivity to Equipment	Low	High
Suggested Pot Temperature	255 – 265 °C	250 – 260 °C
Approximate Relative Cost (Sn63 = 1)	1.5	3.0
Additive	K100LDa	SAC300

SnCuNi+Bi surface finish after wave soldering





Low Dullness

K100*LD* is both doped with a small amount of Nickel to prevent surface shrinkage

Benefits:

- Shininess means that operators don't need inspection training and and AOI equipment doesn't require recalibration
- Lack of shrink holes reduces possibilities of reliability risk

Why is Copper Dissolution Important?

With many lead-free alloys,

Copper level in solder pot increases quickly over time →

Melt point of alloy increases as Copper level increases →

More Copper in the alloy makes it more sluggish →

A more sluggish alloy will cause hole-fill defects increase!

Additionally, alloys that dissolve Copper quickly may completely erode Copper terminations during the soldering process

Why is Copper Dissolution Important?

- By maintaining the Copper level through a low dissolution alloy, Copper levels are practically constant, producing consistent soldering performance
  - This reduces insufficient defects
- No issues with complete erosion of Copper terminations
- Low dissolution also means less maintenance and less use of “additive” bars to lower Copper content in the solder pot

Copper Dissolution Test

Objective:

To determine the Copper Dissolution time in a Solder Alloy

Equipment/Apparatus/Reagent:

- SWET 2100 Wetting Balance
- 0.6 diameter copper wire (U bend wire)
- RMA flux #186
- Stop Watch

Wetting Balance Parameter Setting:

- Test temperature: 300degC (need to ensure solder pot temperature is 300degC by using an external digital thermometer)
- Dipping depth: 5mm
- Speed: 2mm/sec

Test Method:

1. Preclean the copper wire using #5520 and rinse with water and IPA
2. Prepare the copper wire by bending it into a U bend wire [refer to appendix A Picture 1 to 7 for method of bending]
3. Melt the test specimen solder alloy into the inner pot
4. Attached the U bend copper wire onto the holder and dip about 1cm into #186 [refer to Appendix A picture 8]. Attached the holder to the wetting balance.
5. Before the start of the test, stirred the solder alloy in the inner pot for 10 times to prevent segregation of the elements in the solder alloy
6. Start the test which is similar to wetting balance test for chemical flux. Press 'Solder' and then press 'Start'
7. Once the solder pot is raised to the maximum height, press 'STOP' and press the stopwatch simultaneously.
8. Every 5 minutes stirred the solder alloy in the inner pot for 10 times to prevent segregation of the elements in the solder alloy. Take care not to disturbed the copper wire.
9. Note the time taken for the U bend copper wire to disconnect
10. Press 'START" for the solder pot to return to the original position.
11. minimum 3 samples per test

Result:

	SnCuNi1				SAC305				K100LD				SnCuNi2			
	Operator A		Operator B		Operator A		Operator B		Operator A		Operator B		Operator A		Operator B	
Reading	Set A	Set B	Set A	Set B	Set A	Set B	Set A	Set B	Set A	Set B	Set A	Set B	Set A	Set B	Set A	Set B
1	865	850	888	844	460	486	413	427	888	882	902	908	642	700	668	652
2	858	882	863	876	500	470	445	452	973	945	958	961	694	672	648	686
3	901	903	913	907	503	476	540	491	930	1020	1000	1010	691	722	723	722
Ave 1	**874.7**	**878.3**	**888.0**	**875.7**	**487.7**	**477.3**	**466.0**	**456.7**	**930.3**	**949.0**	**953.3**	**959.7**	**675.7**	**698.0**	**679.7**	**686.7**
Std Dev 1	**23.07**	**26.69**	**25.00**	**31.50**	**24.01**	**8.08**	**66.05**	**32.25**	**42.50**	**69.09**	**49.17**	**51.01**	**29.19**	**25.06**	**38.84**	**35.00**
Ave 2	**876.5**		**881.8**		**482.5**		**461.3**		**939.7**		**956.5**		**686.8**		**683.2**	
Std Dev 2	**22.40**		**26.32**		**16.99**		**46.77**		**52.31**		**44.94**		**27.24**		**33.29**	
Ave 3	**879.17**				**471.92**				**948.08**				**685.00**			
Std Dev 3	**23.47**				**35.32**				**47.32**				**29.06**			

Note:

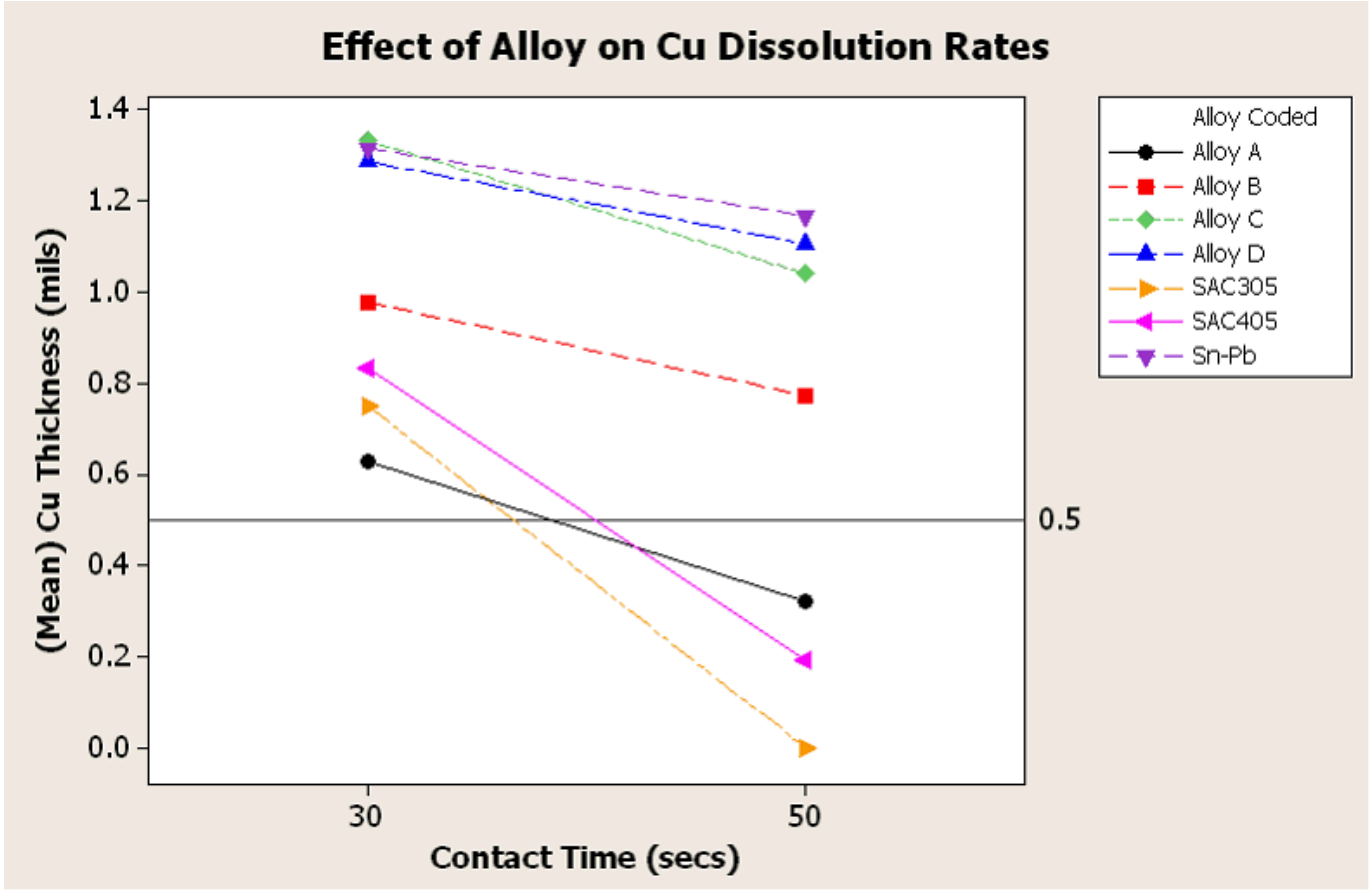
Lowest Dissolution of Copper

Minimizing Copper Dissolution is critical with the conversion to lead-free soldering.

Other lead-free alloys dissolve Copper much faster than K100*LD*:

Alloy	Relative Rate of Copper Dissolution
K100*LD*	0.8
Sn63	1.0
SnCu+Ni	1.0
SAC+Bi	1.6
SAC305	2.1
SnCu	2.2
SnAg	2.3
Pure Tin	2.4

Celestica Independent Study
Copper dissolution on board copper in rework operation



Top is SnPb, blue green, red are SnCuNi, SnCuNi+Bi, SnCu+Co

Low Defects

K100*LD* is designed to give excellent wetting to through-hole and bottom-side SMT components

Dopants in K100*LD* promote fluidity and proper surface tension to yield good hole-fill without bridges

K100*LD* will work with all board and component finishes

Benefits:

- Easy implementation of lead-free process
- Reduction in rework costs and reliability risk

Diminish the 5D's

K100*LD* – Alloy that will Diminish the 5D's

Lowest Dissolution of Copper

- Prevents Copper Erosion and Yields Consistent Soldering Results

Low Dullness

- Produces Shiny, Smooth Solder Joints

Low Defects

- Bridge-free with Excellent Top-Side Fillets

Low Dross

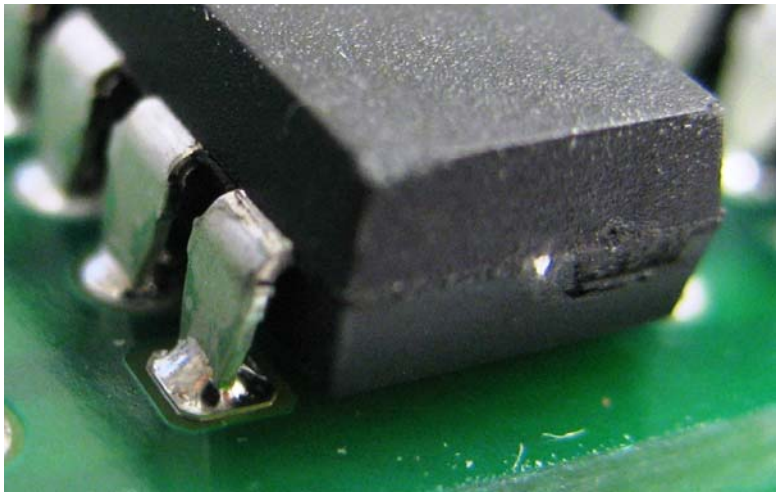
- Anti-Drossing Additive Lowers Drossing by 20% vs. Sn63Pb37

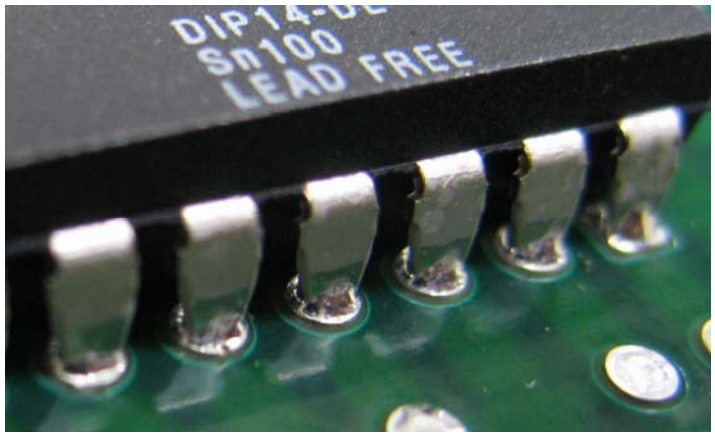
Low Dollars

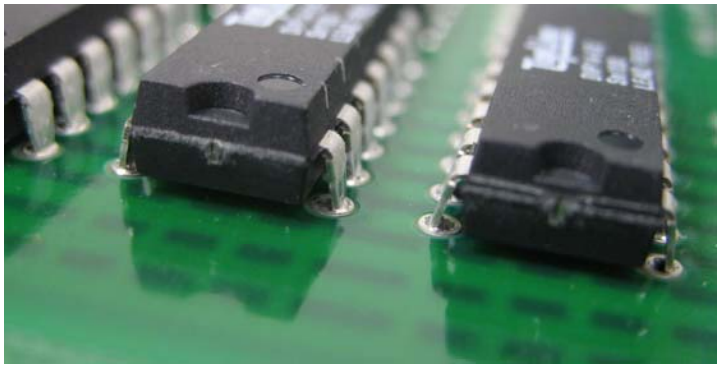
- Silver-Free Alloy is ~50% Lower Metal Cost than SAC305

Comparing to SAC305, SnCuNi, K100LD

All 0.063” AgImm but similar behavior observed with OSP, SnImm, ENIG



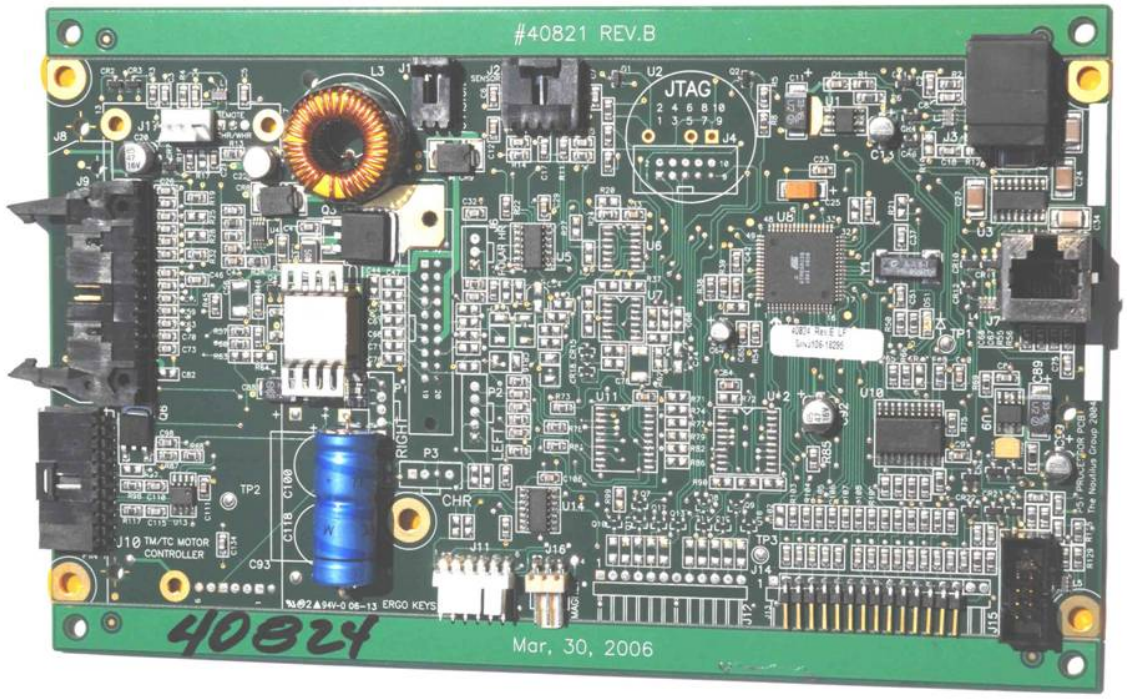




Typical results obtained using no-clean ROL0

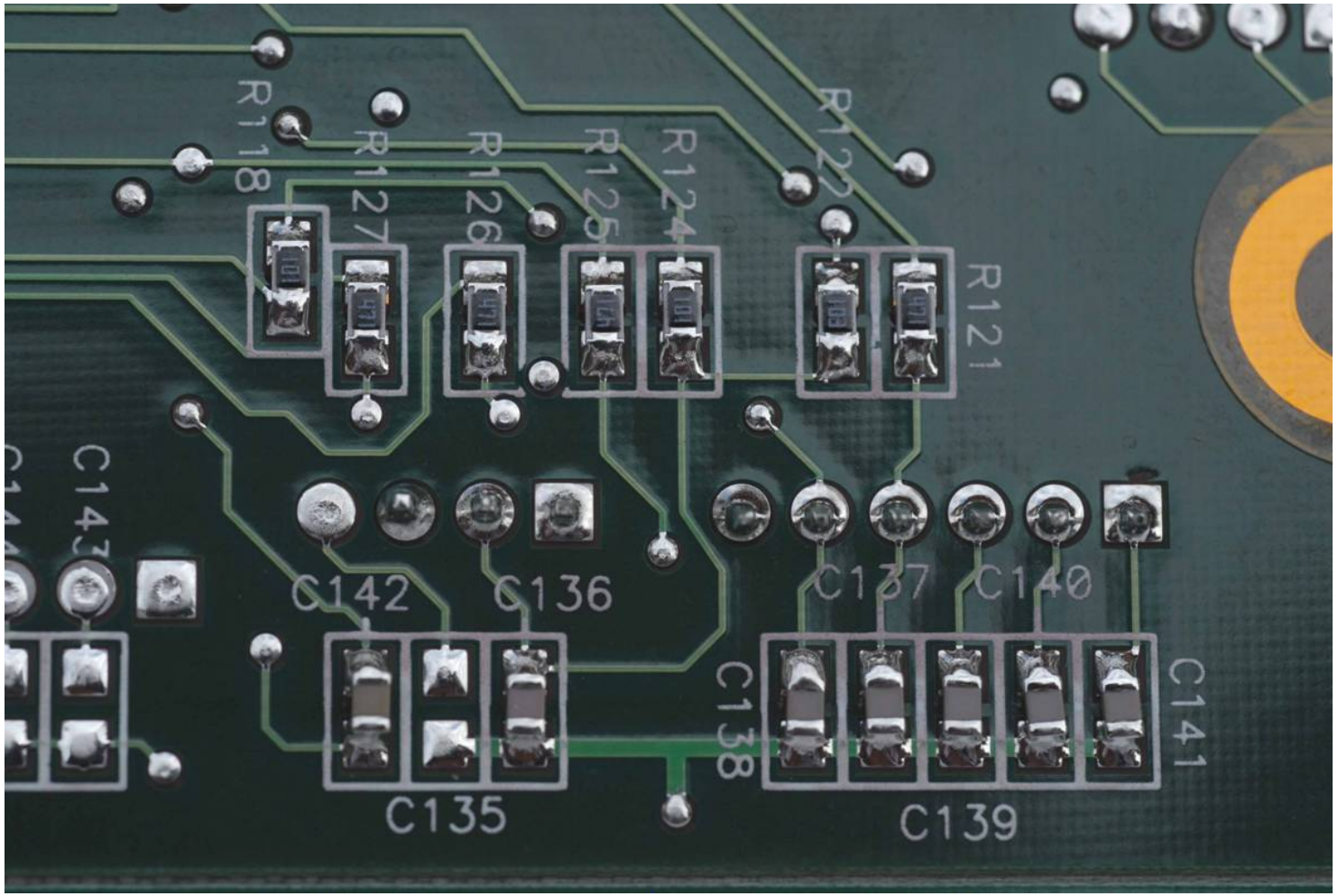
LF Implementation at a Major Contractor Level

They built 12 board types for Nautilus Europe with K100LD, NO-CLEAN ROLO FLUX and SAC305 ROL0 NO-CLEAN solder paste



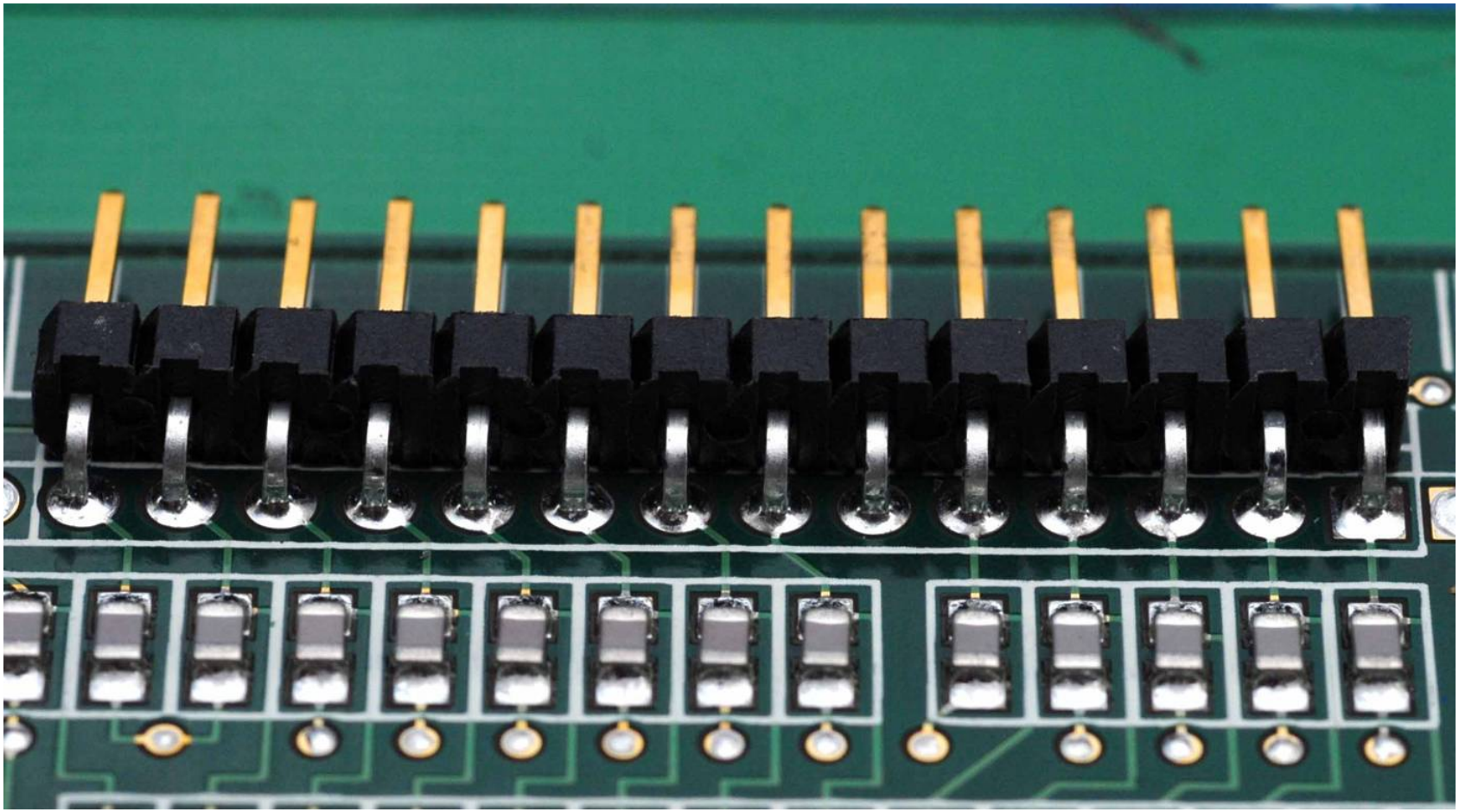
Mixed technology board with top and bottom-side SMDs, 0.063” SN100CL

Bottom-side SMDs and PTHs done with K100LD and N/C flux



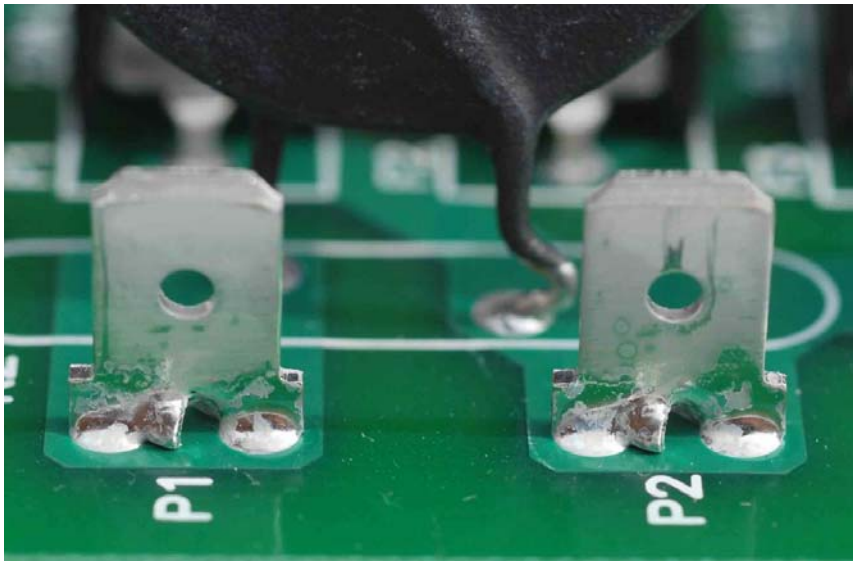
The boards exhibited no defects and bright joints

K100LD Excellent Top-side Fillets; No Dullness, No Shrinkage

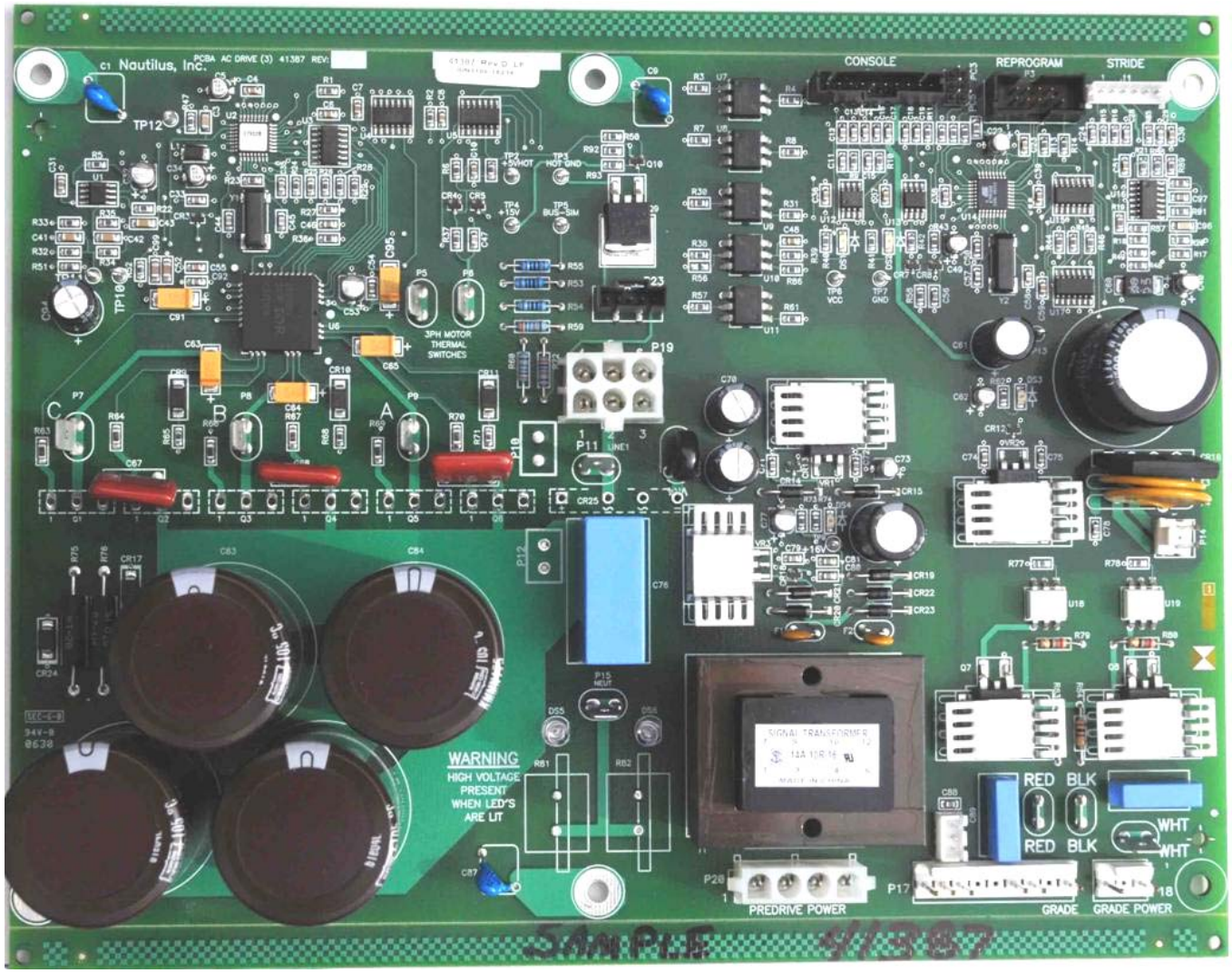


SAC305 N/C used top-side

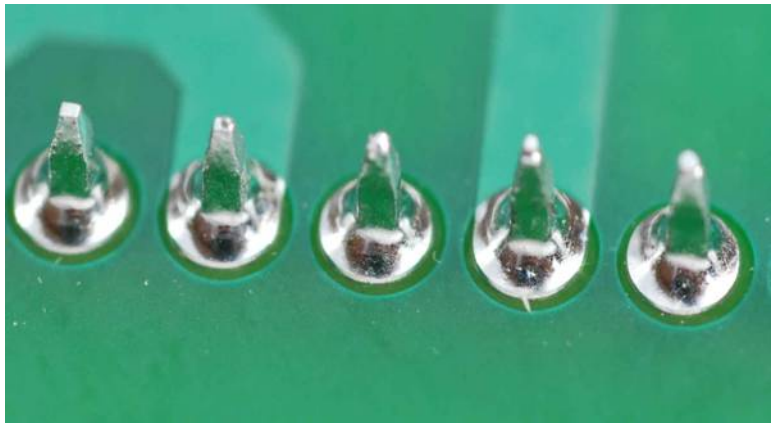
K100LD and low solids no-clean flux ROLO
0.063” SN100CL Finish

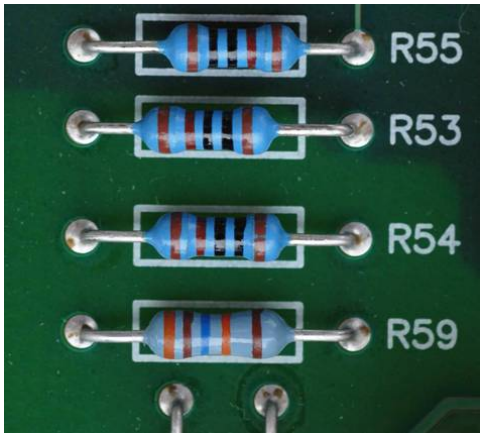


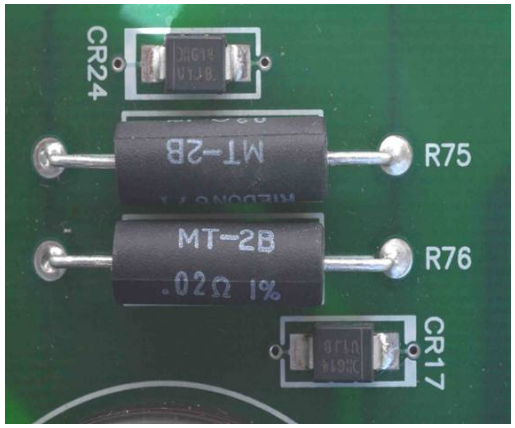
K100LD and NO-CLEAN ROL0 Flux with SAC305 NO-CLEAN ROL0 Top-side reflow, 0.093” Thick SN100CL Finished

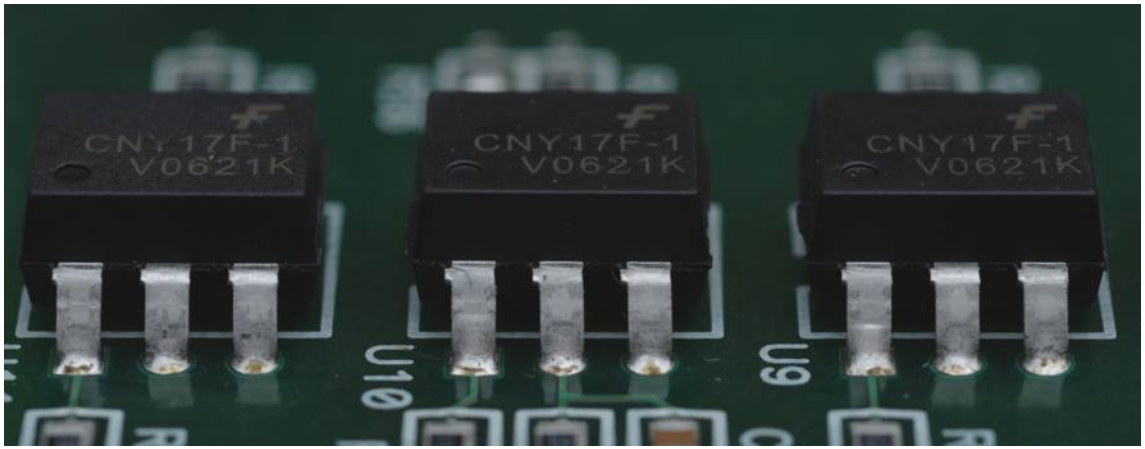


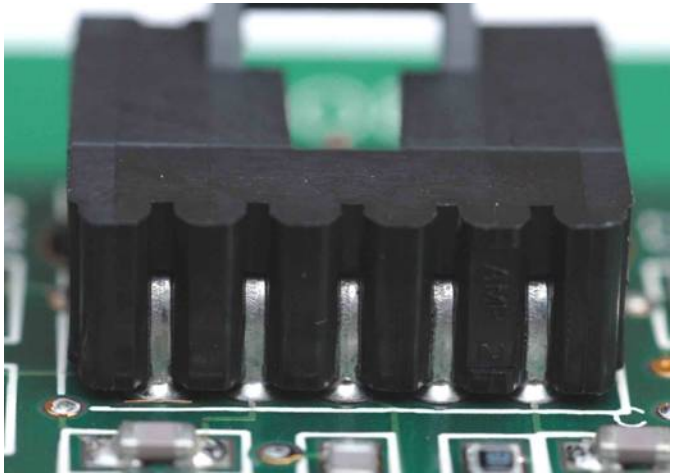
K100LD excellent defect-free bottom-side and top hole-fill











Low Dross

Lead-free alloys generally dross more than leaded counterparts

Due to combination of higher-Tin alloys and higher processing temperatures

Dross formation with lead-free can be 100% greater than traditional leaded process if not controlled via inert environment or anti-drossing technology

Low Dross

K100*LD* is designed with anti-drossing technology to reduce dross rate in wave soldering applications

Anti-dross additive can lower dross rate to 20% less than untreated Sn63

Benefits:

- Lower maintenance time & costs
- Reduced solder usage
- Lower recycling costs & dross handling
- Increased process robustness

Lead-free Wave Soldering Liquid Flux Compatibility
SnCuNi+Bi is compatible with all lead-free fluxes

	VOC-Free (water is solvent)	Alcohol-based
No-Clean, Low Solids, No Rosin	Best for LF *	Not suitable for LF
No-Clean, Low Solids, With Rosin	N/A	Suitable for LF
Organic Acid (Water washable residues)	Best for LF *	Suitable for LF
Rosin-based	N/A	Suitable for LF

* Best selections for lead-free wave soldering, most popular global options today.

SnCuNi+Bi Cored Wire is used for hand-soldering

Testing of tip erosion is ongoing to determine if this alloy erodes tips to a lesser extent than SAC305.

- Compatible with SnCuNi and SnCuNi+Bi solder
- Being used to touch up SAC joints, no problems reported
- Flux percentage in is 3% by weight
- Excellent hole-fill at 700-800°F tip temperatures

Thank-you.

Further information is available.

Contact pbiocca@kester.com