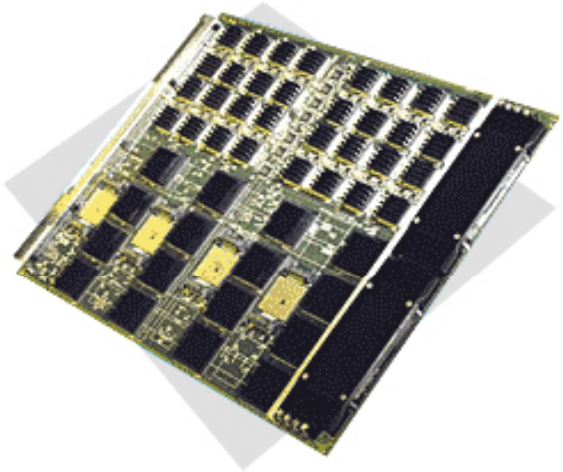
# SnCu Based Alloy Design for Lower Copper Dissolution and Better Process Control



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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

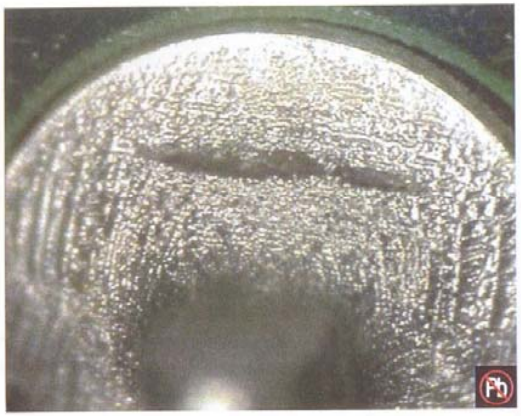


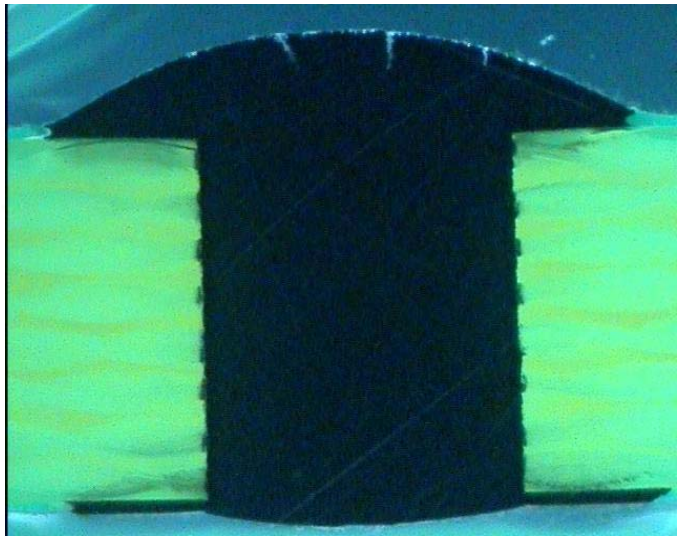
Figure 5-67

**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.

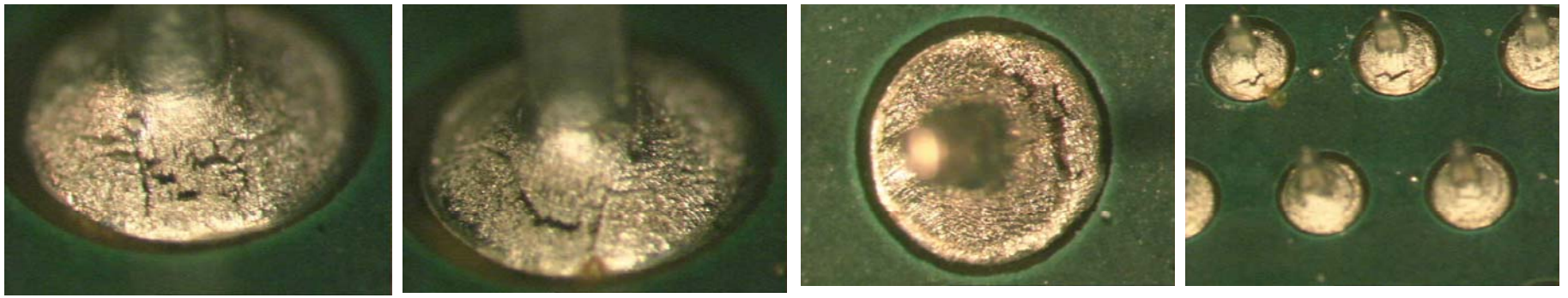
**Defect - Class 1,2,3**

- 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.

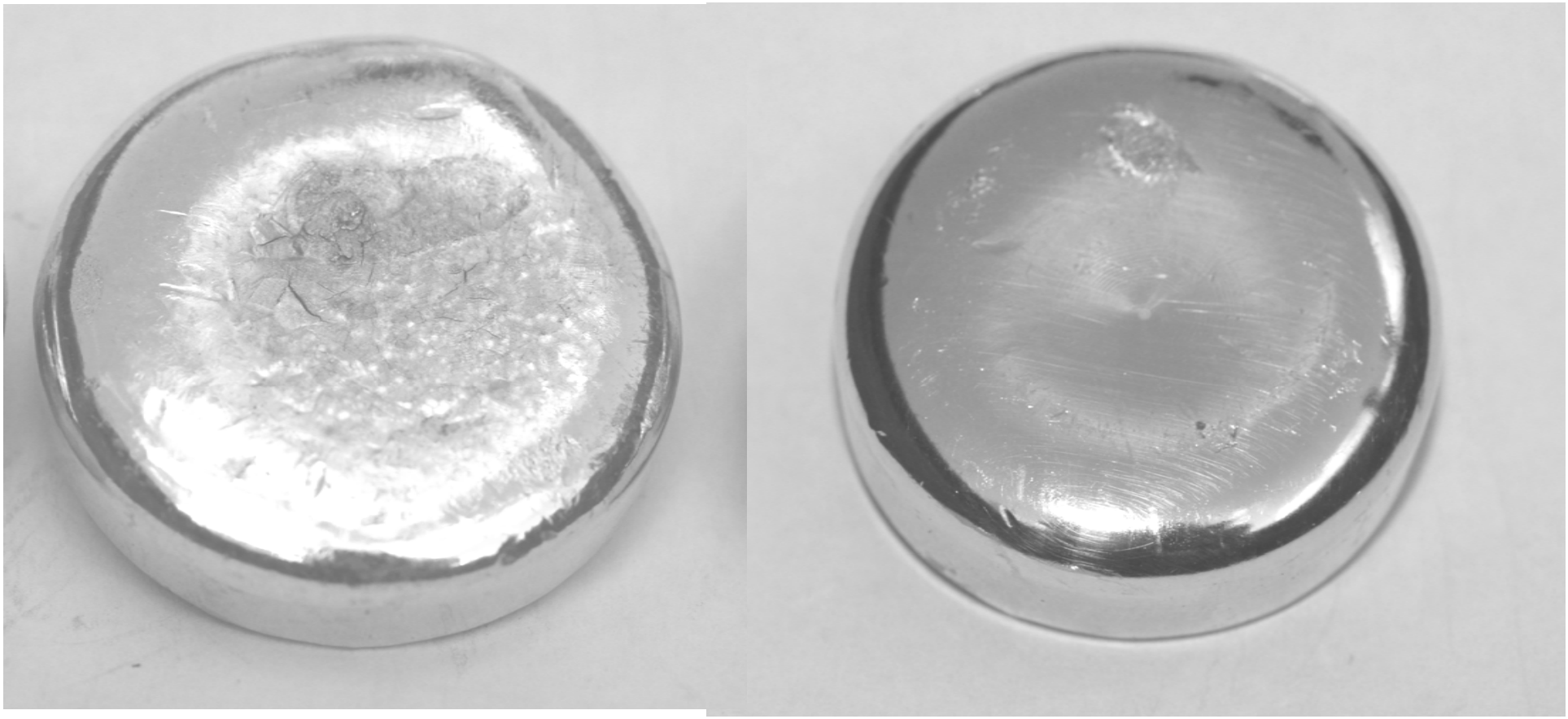


**SAC after 500 thermal cycles, photographs iNemi Lead-free Wave Project 2006, initial work.**

# Surface Cosmetics

## SAC

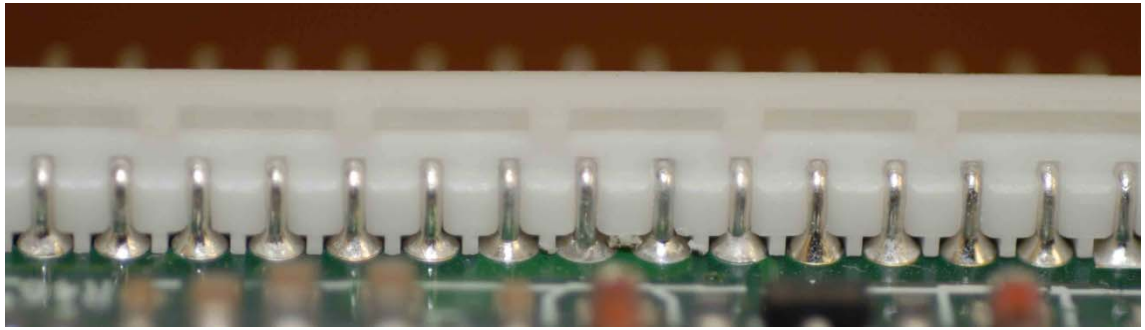
## SnCuNi+Bi

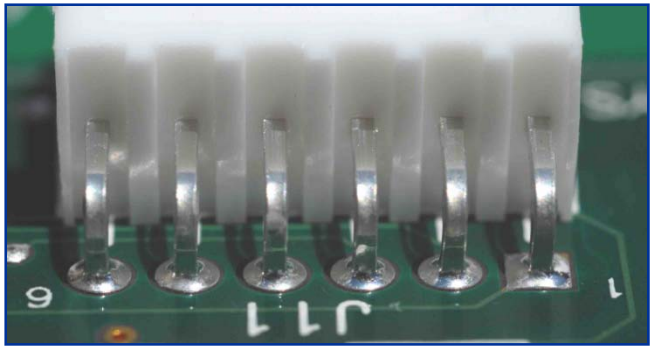


# Alloy properties summary

| | 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:

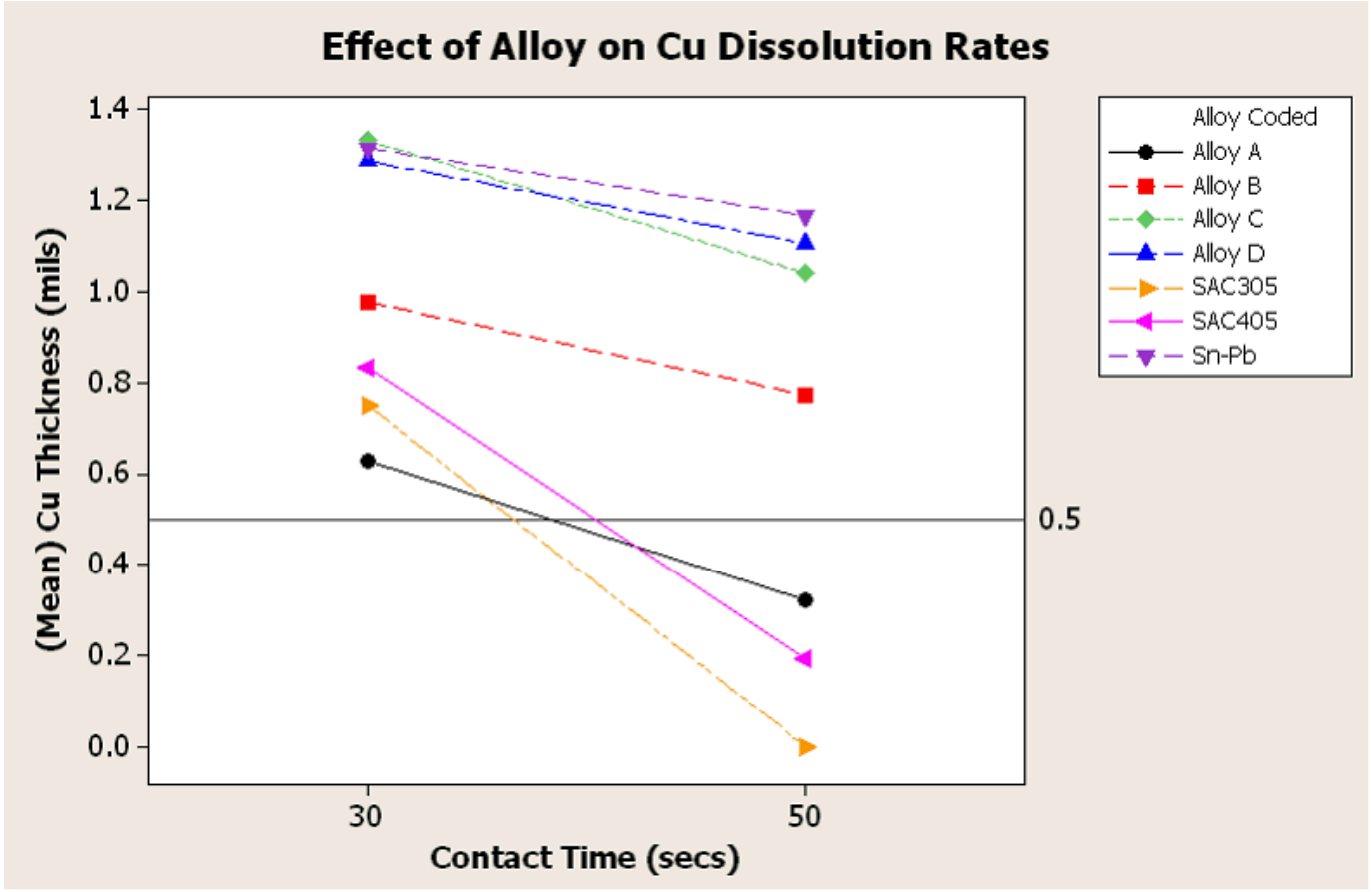
# Lowest Dissolution of Copper

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

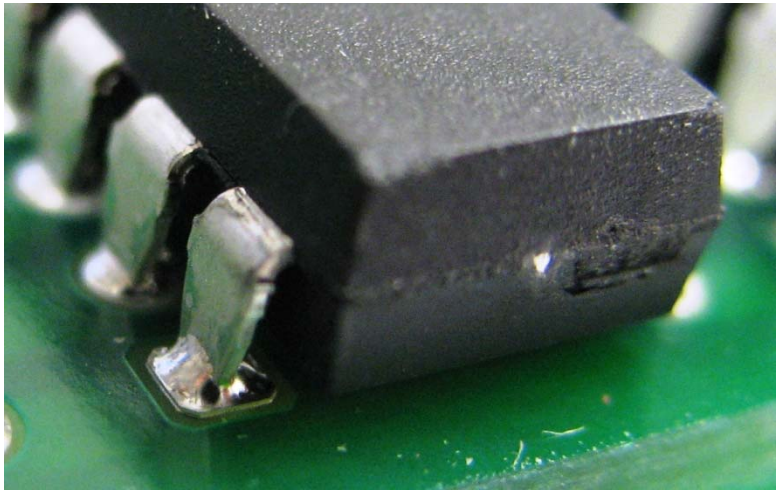
- Anti-Drossing Additive Lowers Drossing by 20% vs. Sn63Pb37

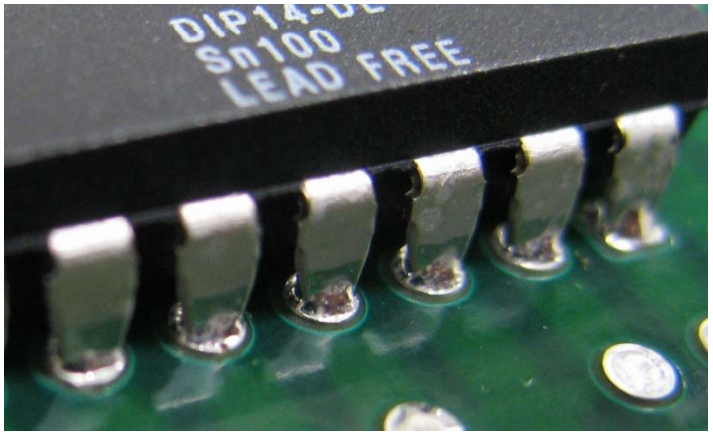
### Low Dollars

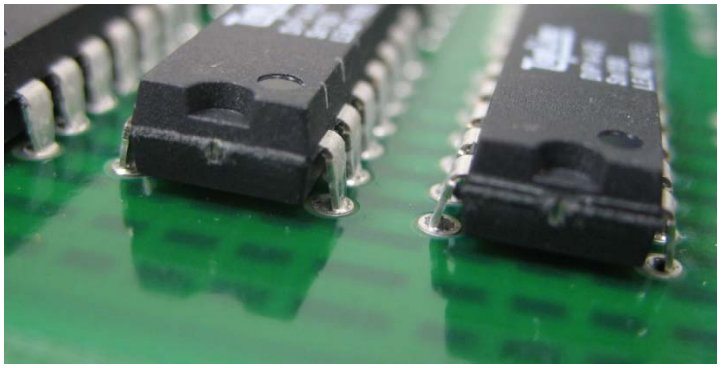
- Silver-Free Alloy is ~50% Lower Metal Cost than SAC305

# Comparing to SAC305, SnCuNi, K100LD

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





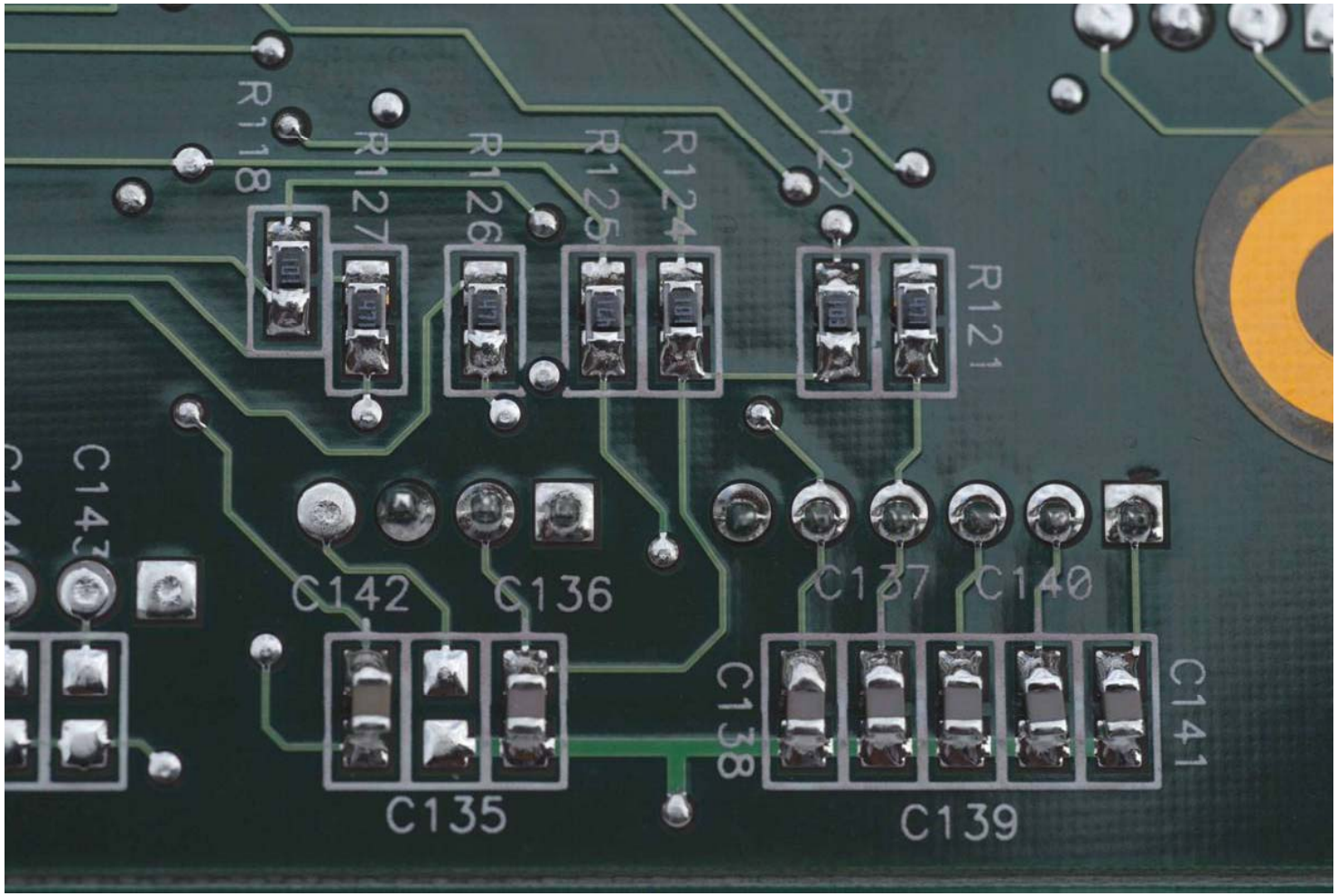
**Typical results obtained using no-clean ROL0**

# 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

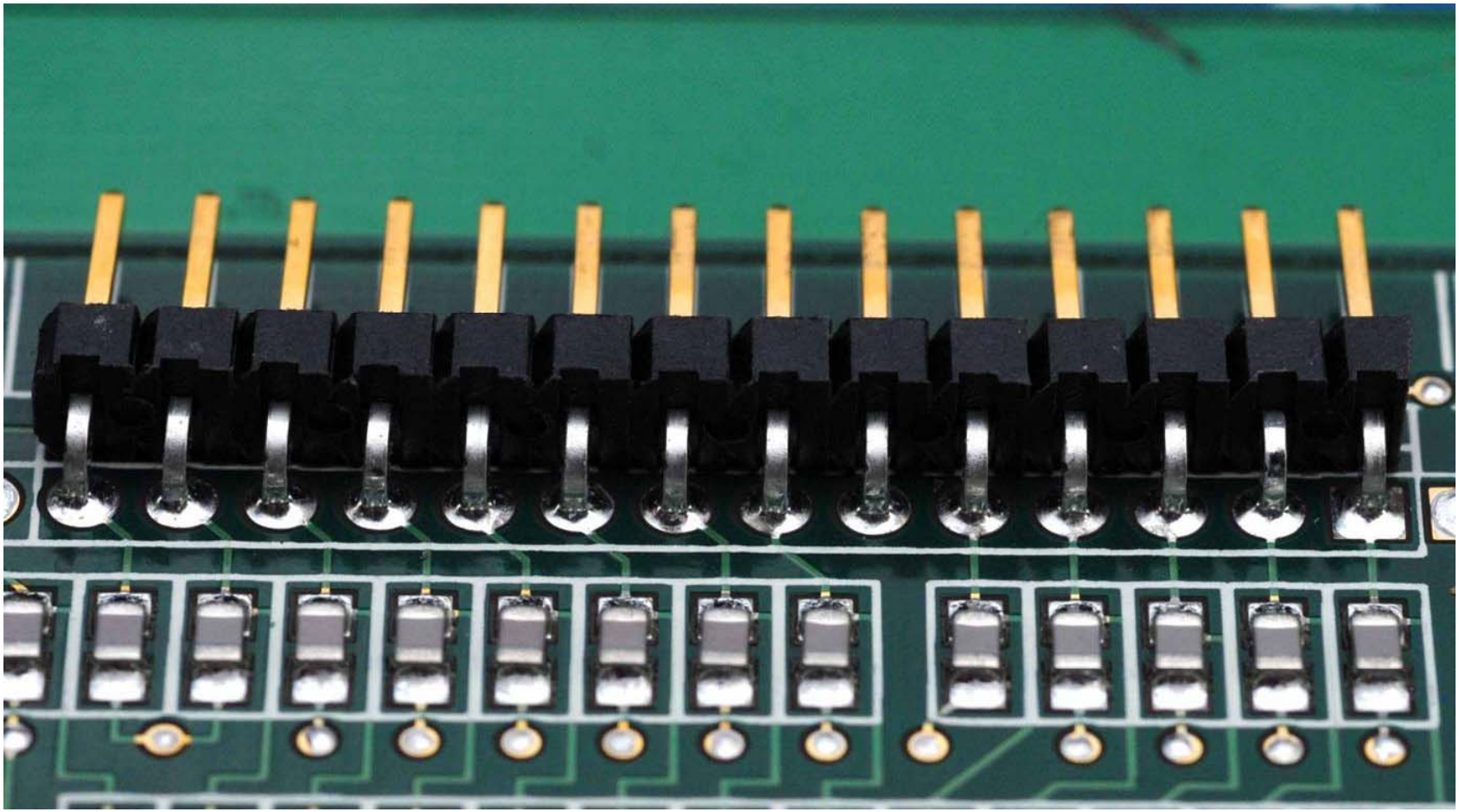

**Mixed technology board with top and bottom-side SMDs, 0.063” SN100CL**

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



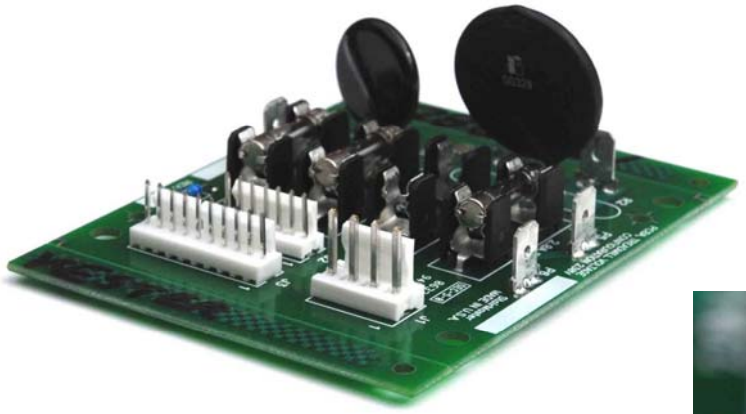

**The boards exhibited no defects and bright joints**

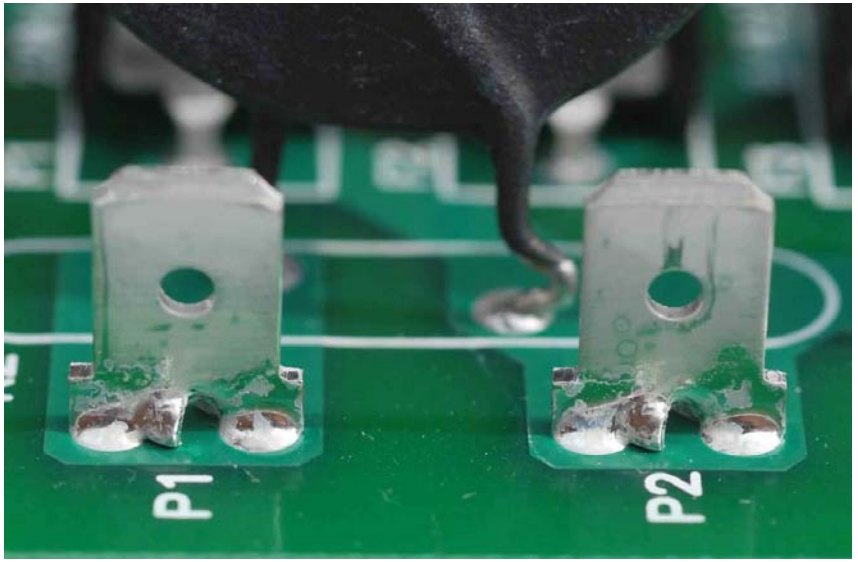
# K100LD Excellent Top-side Fillets; No Dullness, No Shrinkage



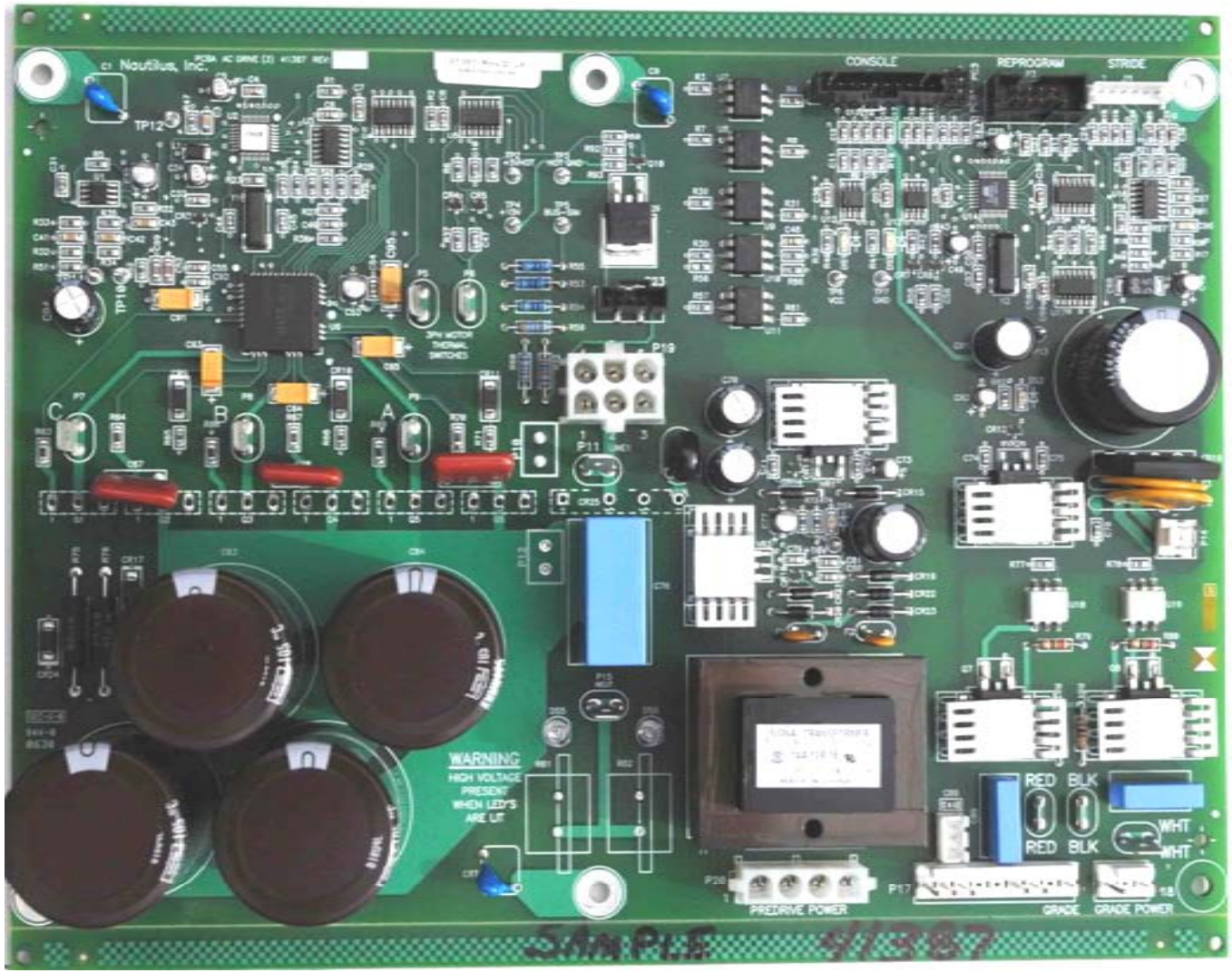
SAC305 N/C used top-side

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

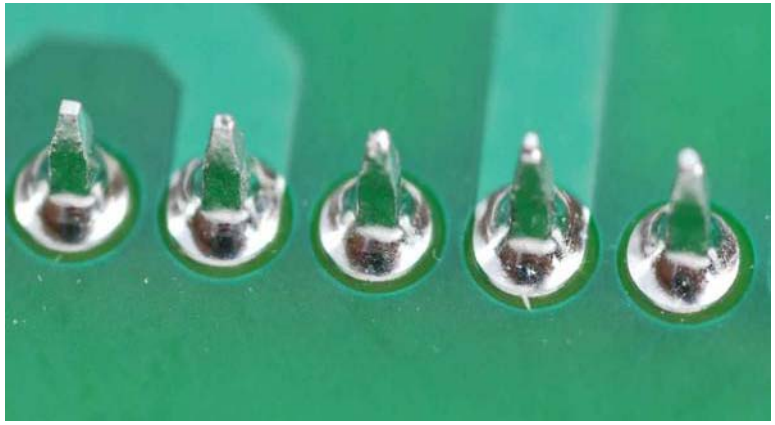


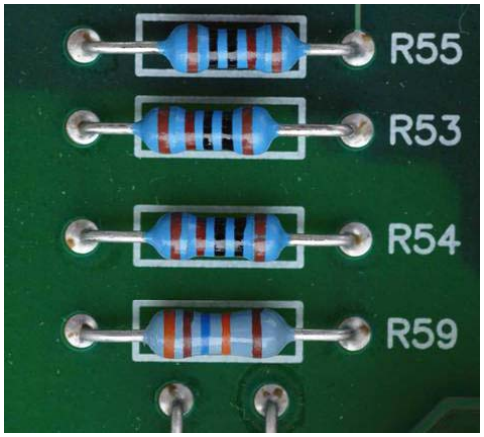


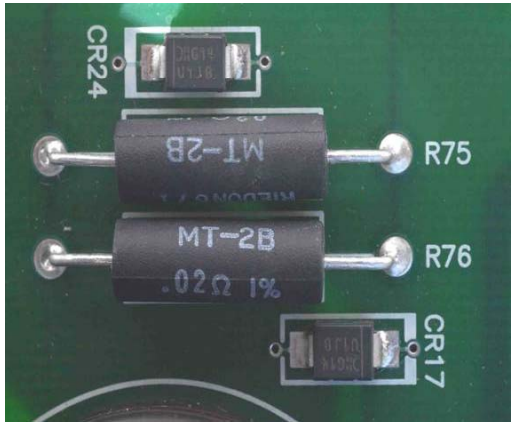
# K100LD and NO-CLEAN ROL0 Flux with SAC305 NO-CLEAN ROL0 Top-side reflow, 0.093” Thick SN100CL Finished

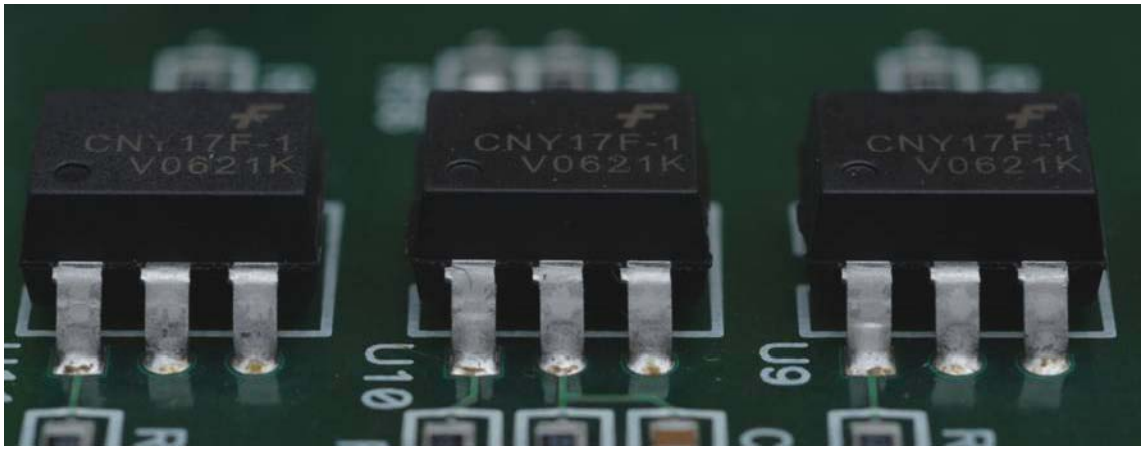


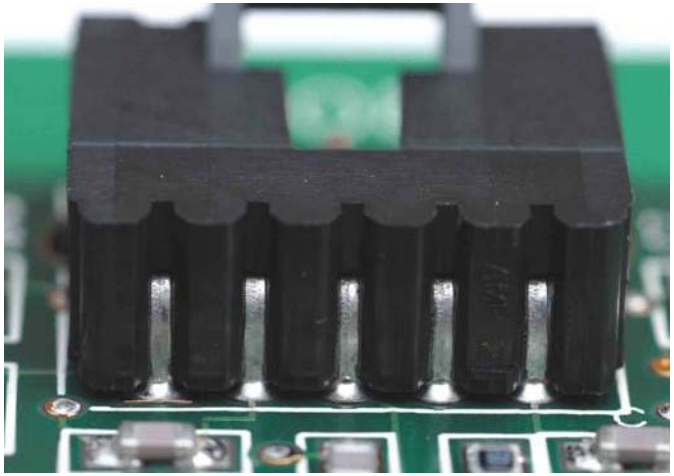
# K100LD excellent defect-free bottom-side and top hole-fill





# 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