SN100C® Technical Guide

Introduction

SN100C is a lead-free tin/copper/nickel/germanium alloy. It has been in use since about the year 2000. Since then SN100C has become a world leading alloy in wave and selective solder applications. SN100C is also used in solder paste, wire solder, lead tinning and hot air solder level (HASL) applications.

SN100C Alloys and Composition

Quality control specifications for fresh solder are shown in the table below.

Element	SN100C	SN100Ce	SN100CL	SN100CLe	SN100C3 or C4
Tin (Sn)	Remainder	Remainder	Remainder	Remainder	Remainder
Copper (Cu)	0.60–0.70%	0%	0.60–0.70%	0%	3.0 or 4.0%
Nickel (Ni)	0.04–0.07%	0.04–0.07%	0.04–0.07%	0.04–0.07%	0.04–0.07%
Germanium (Ge)	0.010% max	0.010% max	0.010% max	0.010% max	0.010% max
Purpose	Wave solder, solder paste, wire solder	Replenisher for wave if copper is high	Hot air solder level makeup only	Replenisher for HASL	Lead tinning

SN100C Additives

Element	Nickel 10 (Ni10)	AO1000
Tin (Sn)	Remainder	Remainder
Copper (Cu)	0%	0%
Nickel (Ni)	10%	0%
Germanium (Ge)	0%	1%
Purpose	Increase nickel	Increase germanium

Solder Shape and Appearance

SN100C and associated alloys are cast in molds which are purged with a nitrogen atmosphere. This limits formation of oxides on the solder bar and keeps the surface bright and shiny. The casting process produces bars that vary a little in shape, size and weight. This is normal and to be expected.

It is possible but uncommon for the bars to take on a light-yellow appearance near the center which is the pour point into the mold. A light-yellow color is the visual indicator of a mild tin oxide which is nanometers thick. This mild tin oxide is cosmetic and has no impact on solder performance.

Normal Operation for Wave / Selective Solder

A fresh solder pot is made up with SN100C, and in most cases SN100C is the only material required to replenish the solder pot. Normal additions to increase the solder level in the pot are usually able to maintain the alloy within operating specification.

As the solder is run, dross formation and removal will change the alloy composition. Dross is mostly comprised of tin oxide, but copper, nickel, and germanium oxides also become part of the dross. Over time, copper and nickel will slowly decrease, but typically stay within specification. Germanium decreases at a faster rate, and occasional additions of AO1000 additive might be required to increase the germanium concentration.

Temperature and "on" time have the greatest effect on the rate of dross formation. Higher temperatures and longer "on" times increase the rate of dross formation. Higher dross rates lead to quicker drop rates in germanium, copper, and nickel concentrations. It is highly recommended to minimize the solder pot temperature, and turn the pot off when not in use.

Effects of Circuit Board Finishes on SN100C Composition in Wave / Selective Soldering

Metals from the solderable finish on the circuit boards will dissolve into the solder and build over time. These can affect the alloy composition, but do not normally require special actions to correct. Common solderable surface finishes and their effects on the SN100C alloy are described below.

Hot Air Level (Pb-Free)

This surface finish is typically SN100CL alloy over copper, which is nearly identical to SN100C. SAC305 is typically not used for Pb-free HASL, due to cost and the high rate of dross formation. The SN100CL surface finish does not add any foreign metals into the SN100C solder, so the SN100C solder will not change composition when this finish is used.

Hot Air Level (Sn-Pb)

This surface finish is typically Sn63/Pb37 solder over copper. Obviously, this finish is not Pb-free, and therefore it will contaminate the SN100C solder pot with Pb. The RoHS limit for Pb is 0.1% by weight maximum.

If Sn-Pb HASL is used, then the Pb concentration in the SN100C solder pot should be monitored closely through frequent analysis. The SN100C solder will have to be corrected when the Pb reaches the RoHS limit. The only practical way to reduce Pb content in SN100C is through dilution. For example, if the Pb content is 0.10% by weight and we want to reduce this to 0.05%, then 50% of the solder will have to be removed from the pot and replaced with fresh SN100C.

Electroless Nickel Immersion Gold (ENIG)

This surface finish is comprised of a thick layer of nickel (100-200 microinches) covered with a thin layer of gold (2-5 microinches). The gold completely dissolves into the SN100C and the solder joint forms on the nickel layer. Over time gold content will increase in the SN100C solder, but this rate of gold increase is very slow. It is very uncommon for gold to exceed the recommended limit when this surface finish is used.

Immersion Silver

This surface finish is comprised of a thin layer of silver (10-15 microinches) over copper. The silver dissolves into the solder and the solder joint forms to the copper pad. A region of SN100C with high silver content may exist near the pad of the board. Over time silver will increase in the solder, but this rate of silver increase is very slow. It is very uncommon for silver to exceed the recommended limit when this surface finish is used.

Immersion Tin
This surface finish is comprised of a thin layer of tin (30-40 microinches) over copper. The tin dissolves into the SN100C and the solder joint forms to the copper. This surface finish does not add any foreign metals into the SN100C solder, so there are no changes to the SN100C alloy composition over time.

Organic Solderability Preservative (OSP)
This surface finish is comprised of an organic solderability preservative over copper. OSP is typically based on imidazole type compounds, and does not contain any metals. There is no contamination of the SN100C solder from the OSP coating itself.

The copper underneath the OSP is dissolved into the solder at a fairly high rate. The activity level of the flux, the temperature of the solder, and the contact time of the solder all affect the rate of copper dissolution into the solder. When a high volume of OSP coated circuit boards are run, then copper in the SN100C solder will climb out of specification fairly quickly.

The best way to compensate for this increase in copper is to use SN100Ce as the replenishment alloy. SN100Ce is the same alloy as SN100C but without copper. SN100Ce can be added in place of SN100C to maintain the solder level in the pot, and as SN100Ce is added the copper concentration will drop. The copper content should be monitored closely through frequent analysis. As SN100Ce is used, there may be a point where the copper level drops near the low end of the specification range. If this occurs, then SN100Ce should no longer be used and SN100C should be used for replenishment. SN100Ce should only be used on a temporary basis when copper is high.

Hard/Soft Gold
This surface finish is comprised of a thick layer of gold (40-60 microinches) plated over a thick layer of nickel (100-200 microinches). Some of the gold layer dissolves into the SN100C solder, and as this surface finish is used over time the gold concentration may exceed the specified maximum. The best way to reduce the gold concentration in SN100C is through dilution. For example, if the gold content is 0.08% by weight and we want to reduce it to 0.04%, then 50% of the solder will have to be removed from the pot and replaced with fresh SN100C.

SN100C Working Solder Pot Specifications

Element	Recommended Range (% wt.)	Effects if Out of Specification
Tin (Sn)	Balance	N/A
Copper (Cu)	0.50 – 0.85	See text below table
Nickel (Ni)	0.02 – 0.07	See text below table
Germanium (Ge)	0.010 max	See text below table
Aluminum (Al)	0.002 max	Potential embrittlement in solder joint

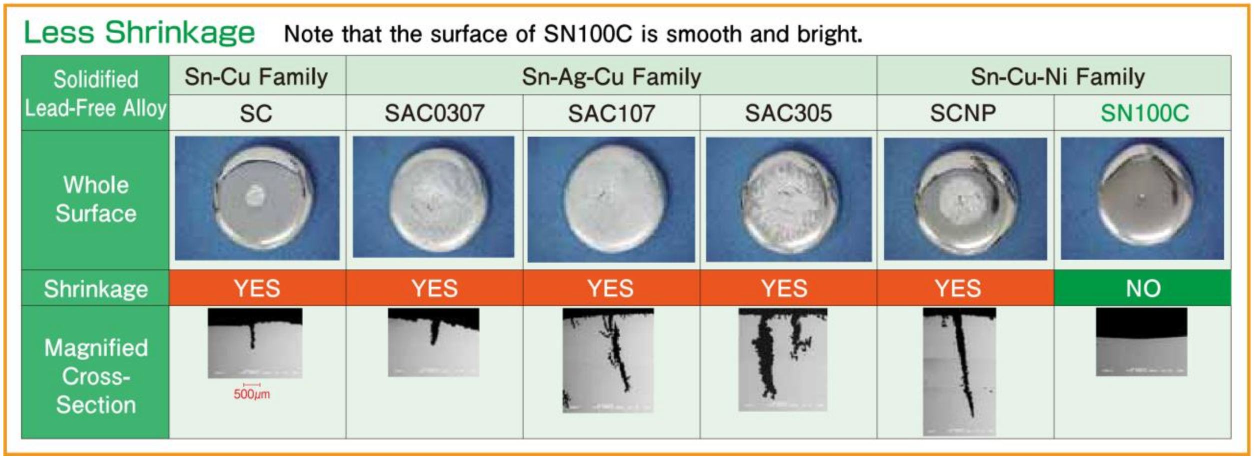
Antimony (Sb)	0.05 max	Increase of melting point
Arsenic (As)	0.03 max	Unknown
Bismuth (Bi)	0.05 max	Lowering of melting point
Cadmium (Cd)	0.005 max	Unknown
Gold (Au)	0.08 max	Potential embrittlement of the solder joint
Iron (Fe)	0.02 max	Unknown
Lead (Pb)	0.10 max	No longer RoHS compliant
Silver (Ag)	0.05 max	Potential embrittlement of the solder joint
Zinc (Zn)	0.005 max	Potential embrittlement of the solder joint

Copper (Cu), nickel (Ni), and germanium (Ge) are the key elements in the SN100C alloy. It is very important to control these within specified ranges or the solder will not perform optimally.

- Low copper: the solder can become dull looking. Melting point increases closer to that of pure tin which is 232°C.
- High copper: solder can become dull/grainy looking. Melting point increases and the solder takes on a melting range because it is no longer eutectic. The rate of dross formation might increase due to the higher level of copper. Barrel fill is less than optimal, and bridging/icicling might become an issue.
- Low nickel: solder will become dull looking. Bridging/icicling may become an issue. The intermetallic of tin/copper will no longer be stabilized by nickel. Over time, the intermetallic layer of solder joints will grow and could lead to mechanical strength issues.
- High nickel: no major issues, but also no added benefit above a nickel content of about 0.07% by weight.
- Low germanium: dross rate will increase. Germanium is an anti-oxidant, and is the primary dross inhibitor in the SN100C solder. Bridging/icicling might become an issue.
- Low germanium may lead to a yellow color forming on the solder joints. Yellow coloration is due to tin oxide formation. Tin oxide causes mainly a cosmetic change and is not indicative of solder joint reliability.
- High germanium: no major issues, but also no added benefit above a germanium content of about 0.010% by weight.

SN100C Compared to Competitive Alloys

There are many competitive alloys to SN100C on the market that are based on the Sn/0.7Cu alloy. These alloys all share one common issue, the composition has to be modified to be different from that of SN100C in order to avoid patent violations. When nickel and/or germanium are not used at the proper concentrations, then performance suffers. Here is a brief summary of these alloys.



	SN100C	SAC0307	K100LD	SN995	SC995e / SN100e
Alloy	Sn/Cu/Ni/Ge	Sn/0.3Ag/0.7Cu	Sn/0.7Cu/X	Sn/0.5Cu/Co/X	Sn/0.5Cu/Co
Patent avoidance	N/A	Low silver addition	Low nickel, added phosphorous	Cobalt replaces nickel	Cobalt replaces nickel
Grain refinement	Yes	No	No	No	No
Stable intermetallic	Yes	No	No	No	No
Stable composition	Yes	No	No	No	No

Comments about additives used in Sn/Cu based solders:

- Nickel is used at a proper level in SN100C and the benefits are grain refinement and stabilization of the intermetallic of the solder joint. Nickel also improves fluidity which provides good hole fill and wetting. Some competitive alloys use nickel at levels below the proper range. Nickel is not as effective at low levels, so some of the benefits are lost.
- Germanium is used at a proper level in SN100C. It is the primary anti-oxidant in SN100C which reduces the rate of dross formation. Germanium also improves bridging and icicling performance by promoting good drainage of the solder. Germanium might be used in competitive solders below the proper level. Germanium is not as effective at low levels, so some of the benefits are lost.
- Silver is well known as an additive to Sn/Cu solders. It causes a dull appearance and graininess in the solder, and produces shrinkage cracks. Silver adds a significant amount to the cost of the solder. Silver is also known to promote corrosion to the solder pot, and dramatically increases the rate of dross formation.
- Cobalt gives some improvement to the fluidity of the solder which improves hole fill and wetting. Cobalt is unstable and forms compounds which separate from the bulk solder, leading to a drop in cobalt concentration. Cobalt also does not stabilize the intermetallic of the solder joint. Intermetallic growth over time can lead to mechanical failure of the solder joint.

- Phosphorous is sometimes used as a dross inhibitor. Phosphorous dramatically reduces the fluidity of the Sn/Cu solder which leads to issues with hole fill and wetting. Phosphorous also can promote corrosion of solder pots which shortens the life of the equipment.