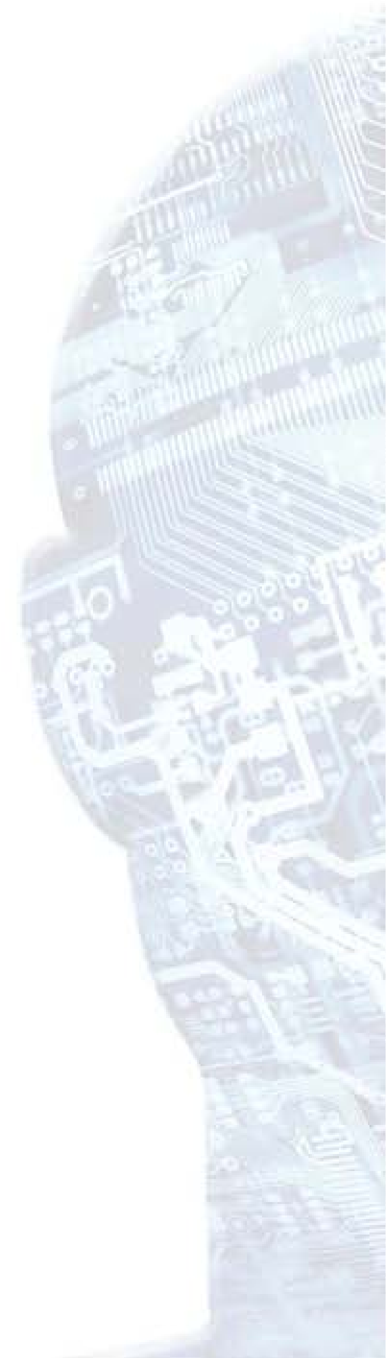
BALVER ZINN®

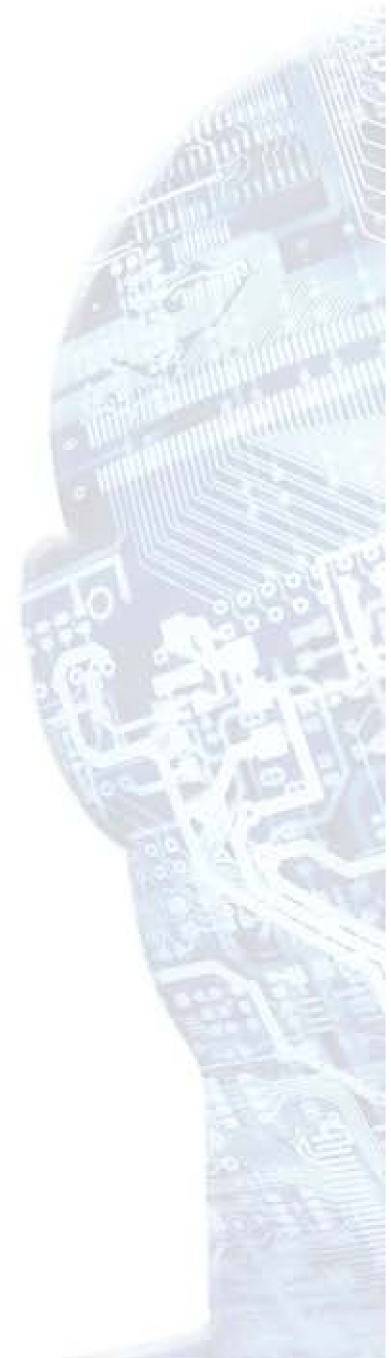
How to manage wave solder alloy contaminations

Gerjan Diepstraten & Harry Trip
Cobar Europe BV
Balver Zinn



Content

- SnPb solder and impurities
- Lead-free solder change
- Pb contaminations in lead-free
- Measure solder composition
- Sample interval
- Recommendations
- Wave soldering versus selective



Dissolution of Base Metals in SnPb

Rate of dissolution:

- Base metal
- Solder composition
- Solder temperature
- Flow velocity

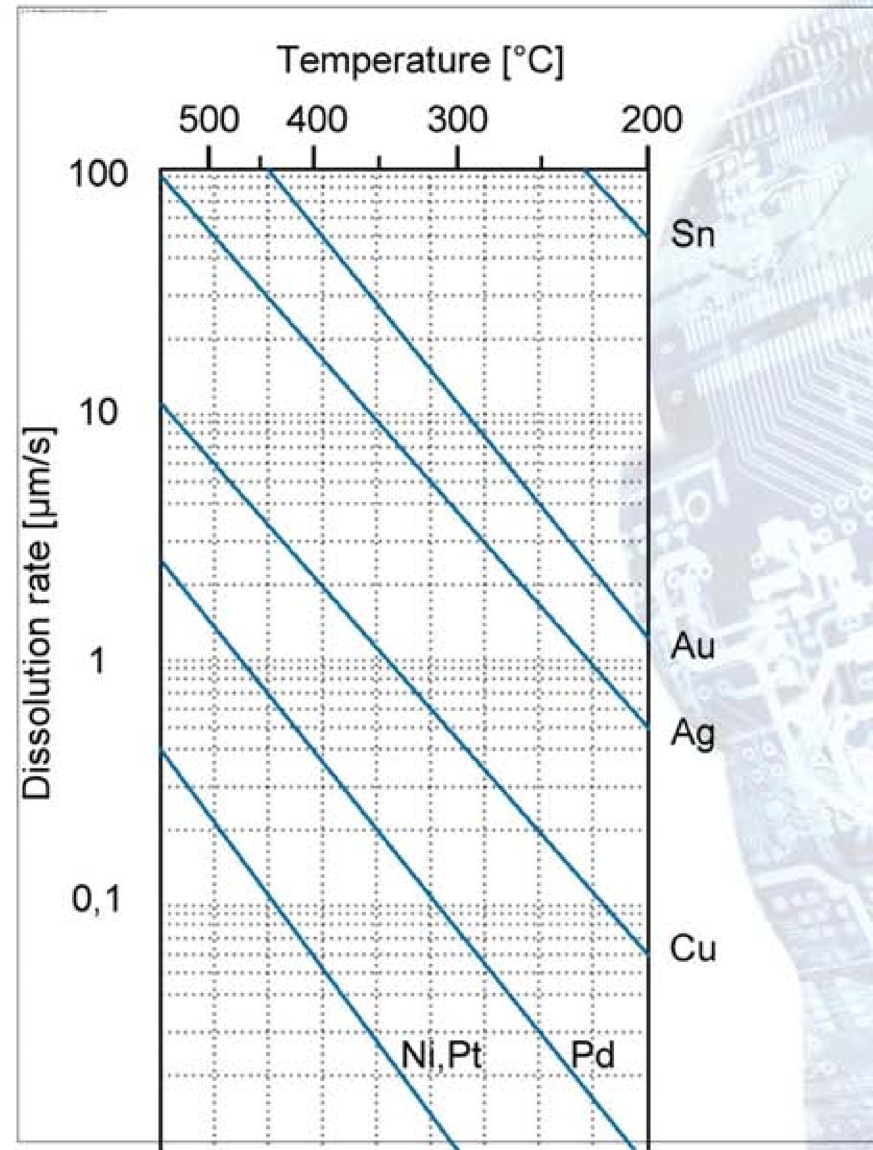
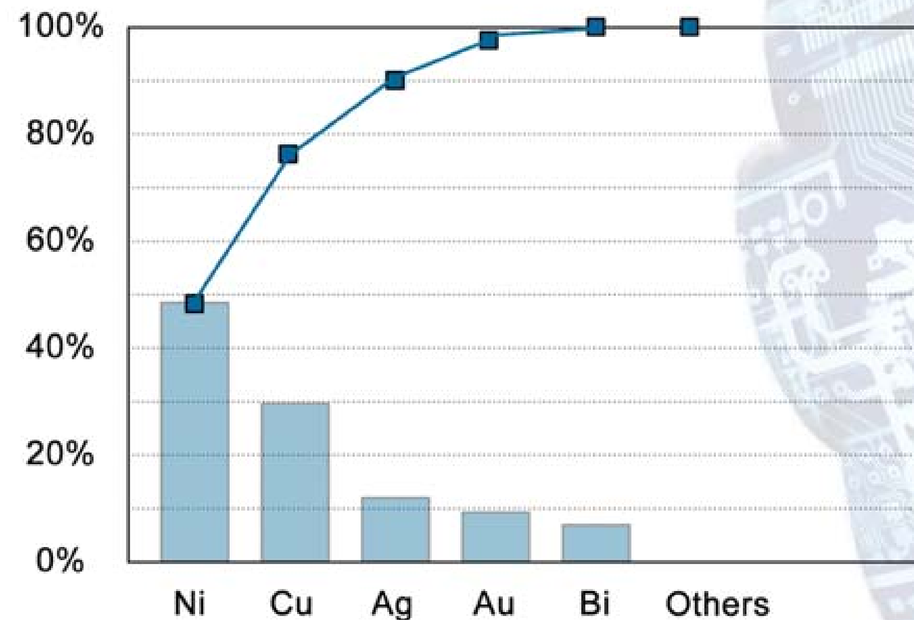


Fig. 4.29 Soldering in Electronics
R.J. Klein Wassink

SnPb impurities

Contaminant	Max.limit
Copper	0,3
Gold	0,2
Cadmium	0,005
Zinc	0,005
Aluminium	0,006
Antimony	0,5
Iron	0,02
Arsenic	0,03
Bismuth	0,25
Silver	0,1
Nickel	0,01
Total of Cu,Au Cd, Zn and Al	0,4

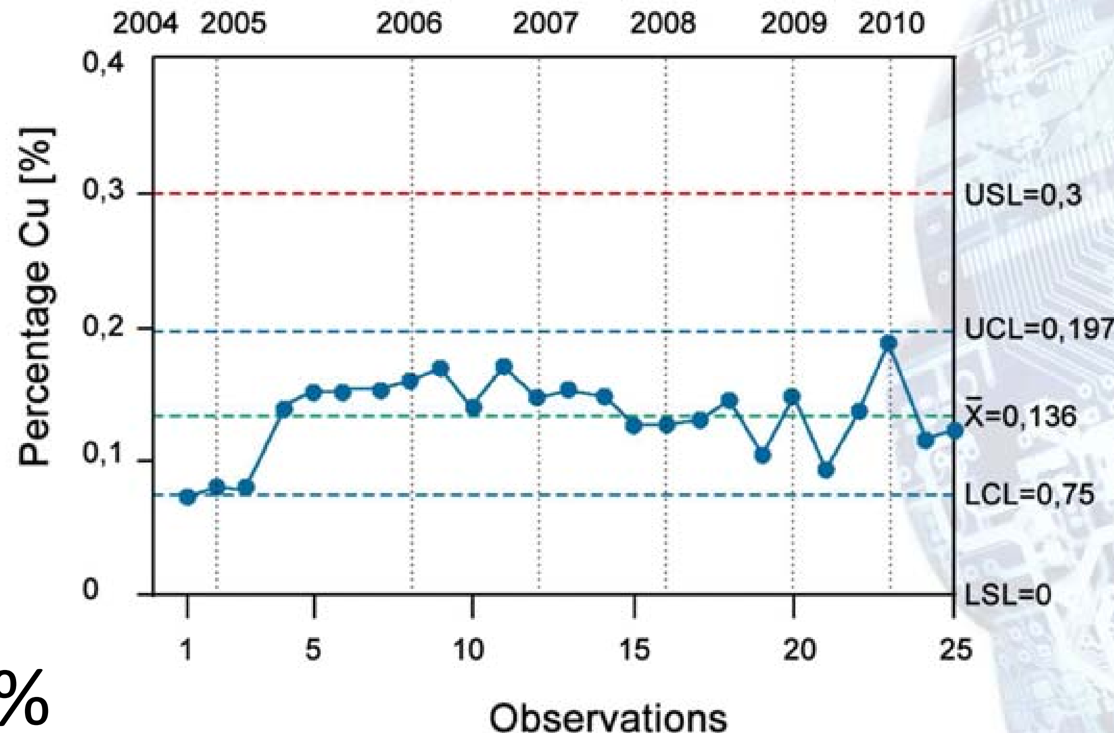
Out of specification:



Limits according to IPC-J-STD001E

Scores from >1500 solder pot analysis

Copper contamination in SnPb



Maximum 0,3%

Remove at 190 °C with stainless steel strainer

Exchange solder

Procedure:

1. Empty solder pot
2. Clean all parts
3. Refill pot with pure Sn (wash Sn)
4. Run solder pumps for > 0,5 hour
4. Empty solder pot
5. Refill solder pot with lead-free solder

Solder exchange – Sn wash

Lead-free alloy exchange solderpot				
Remaining SnPb [kg]	Selective pot [50 kg]	Small wave pot [400 kg]	Typical wave pot [800 kg]	Large wave pot [1000 kg]
10	8,179	1,046	0,524	0,419
5	4,144	0,524	0,262	0,210
2	1,671	0,210	0,105	0,084
1	0,838	0,105	0,052	0,042
0,5	0,419	0,052	0,026	0,021
0,1	0,084	0,010	0,005	0,004

Percentage of Pb after lead-free refill

Use wash Sn to get low Pb impurities

Lead-free alloy exchange solderpot with Sn wash				
Remaining SnPb [kg]	Selective pot [50 kg]	Small wave pot [400 kg]	Typical wave pot [800 kg]	Large wave pot [1000 kg]
10	1,834	0,030	0,008	0,005
5	0,470	0,008	0,002	0,001
2	0,076	0,001	0,000	0,000
1	0,019	0,000	0,000	0,000
0,5	0,005	0,000	0,000	0,000
0,1	0,000	0,000	0,000	0,000

Spectro analysis

1. Sample: flowing solder middle of the wave
2. Preparation sample
3. OES Analysis

Erosion solder pot

Erosion

Lead-free:

- Higher solder temperatures
- Higher Ag & Sn content
- Lack of Pb lubrication

Potential alternatives:

Titanium

Cast iron

Chrome carbid

Ag-less alloys

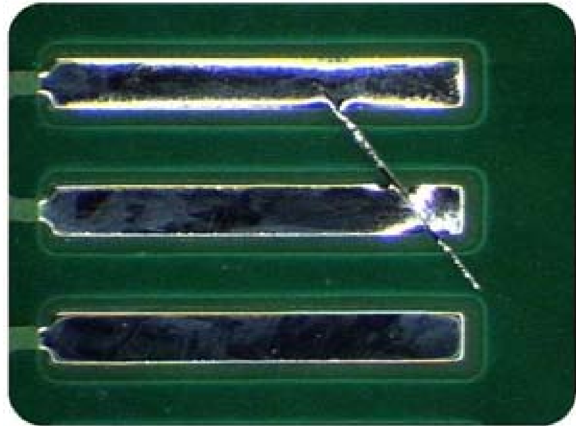
Fe contamination

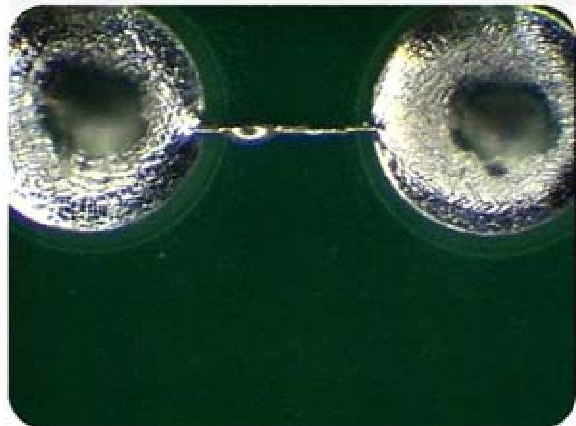
- $FeSn_2$ needles
- SAC alloys sensitive for erosion
- Co or Ni doping to minimize erosion

	SnPb	SAC	SN100C
Average	0,0027	0,0020	0,0021
Standard dev.	0,00055	0,00259	0,00237

Fe Max. Values 0,02 %

SPC Chart Fe contamination





$FeSn_2$ needles:

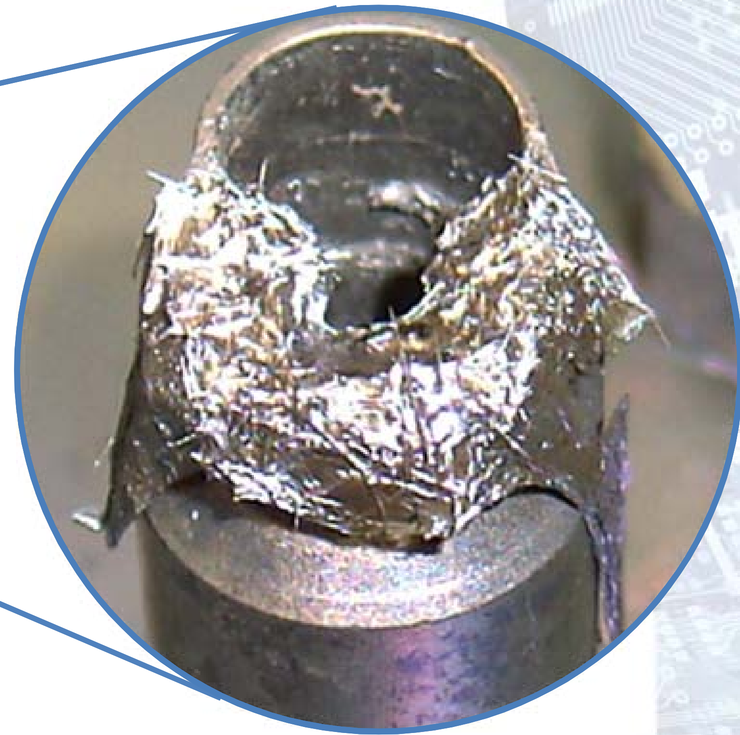
- Melting point >500 °C
- In areas where there is no flow
- Bridging potentials

Hard to define iron erosion by analyzing solder samples

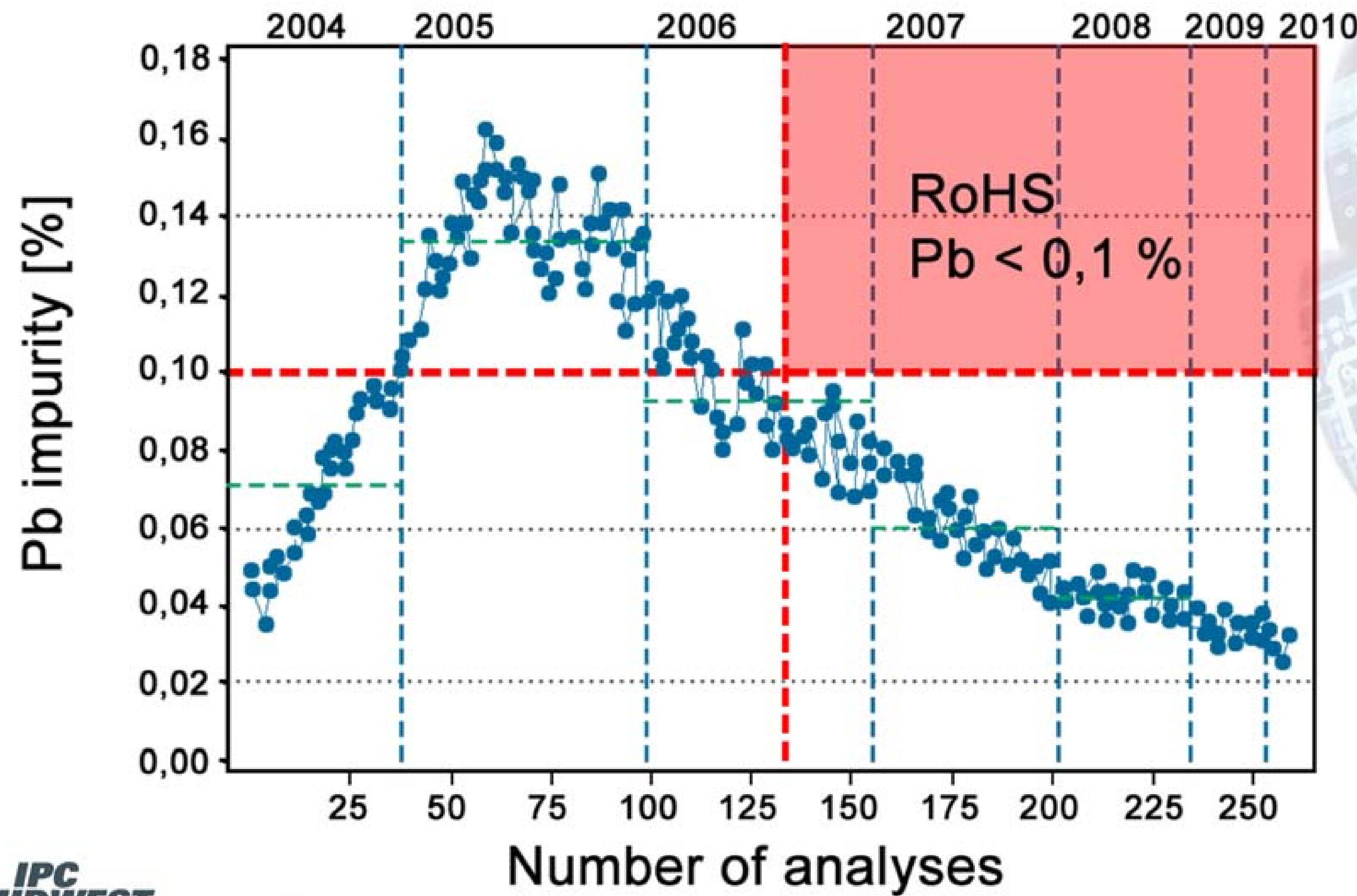
$FeSn_2$ Needles Selective SnPb

Also in SnPb alloys there is steel erosion.

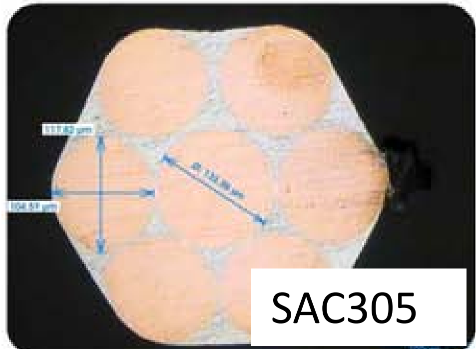
Reduces flow properties.

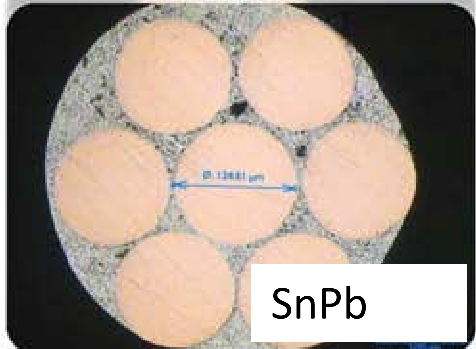


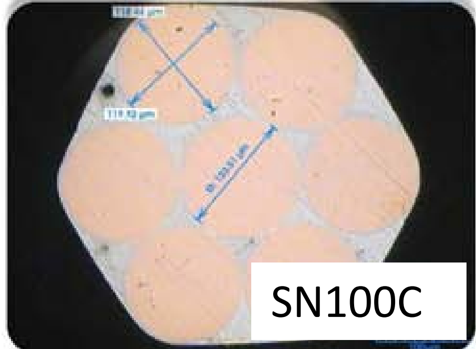
Pb impurity historical graph

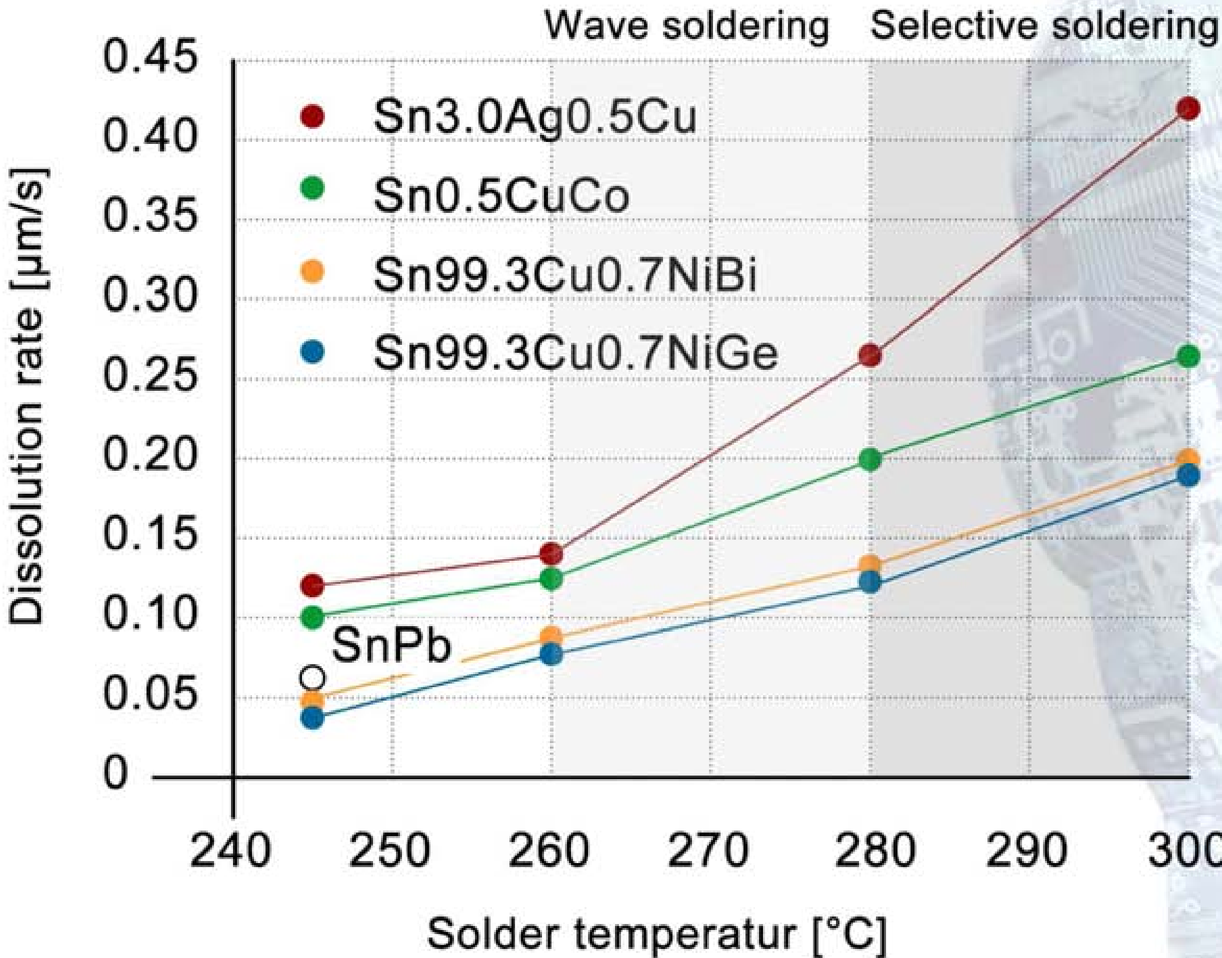


Copper leaching



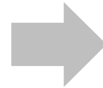


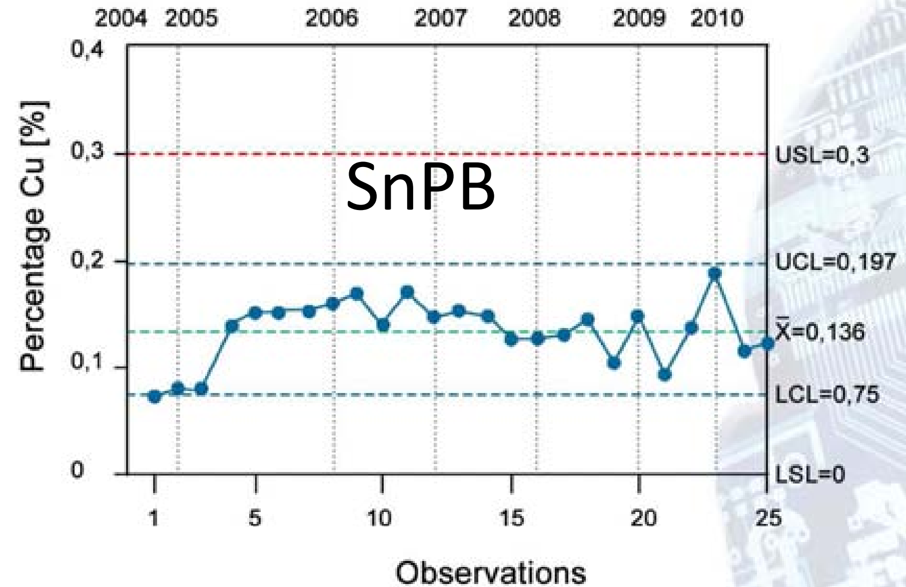




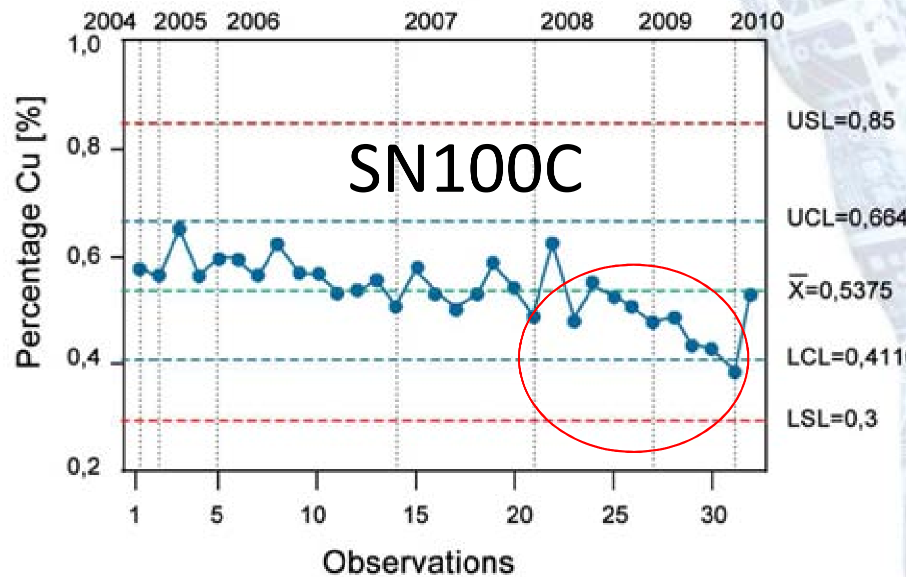
SPC: Cu content in solder

Nitrogen wave solder process (full tunnel) (identical machines, same customer):
Automotive, Medical products (SnPb)

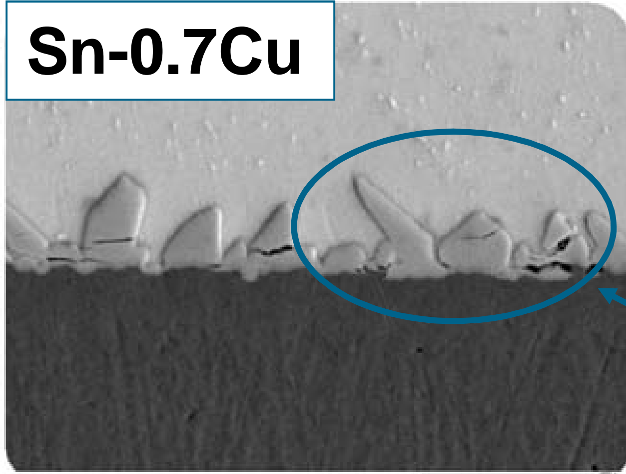


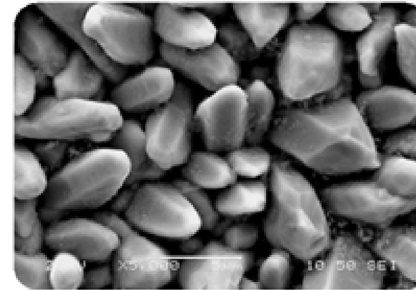


Industrial (lead-free)

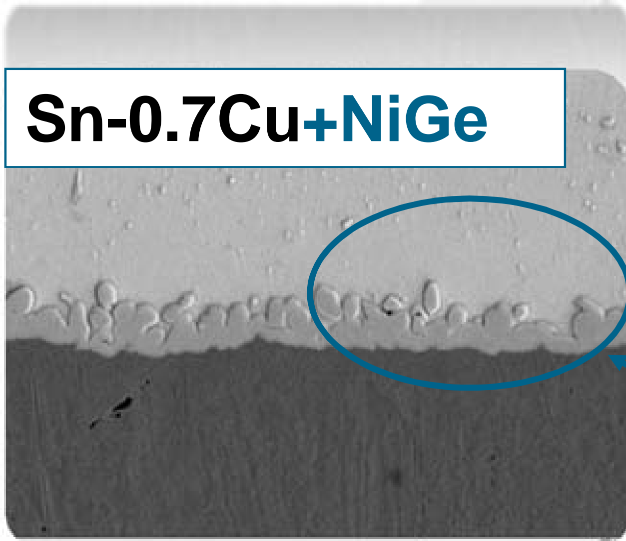


Ni additive





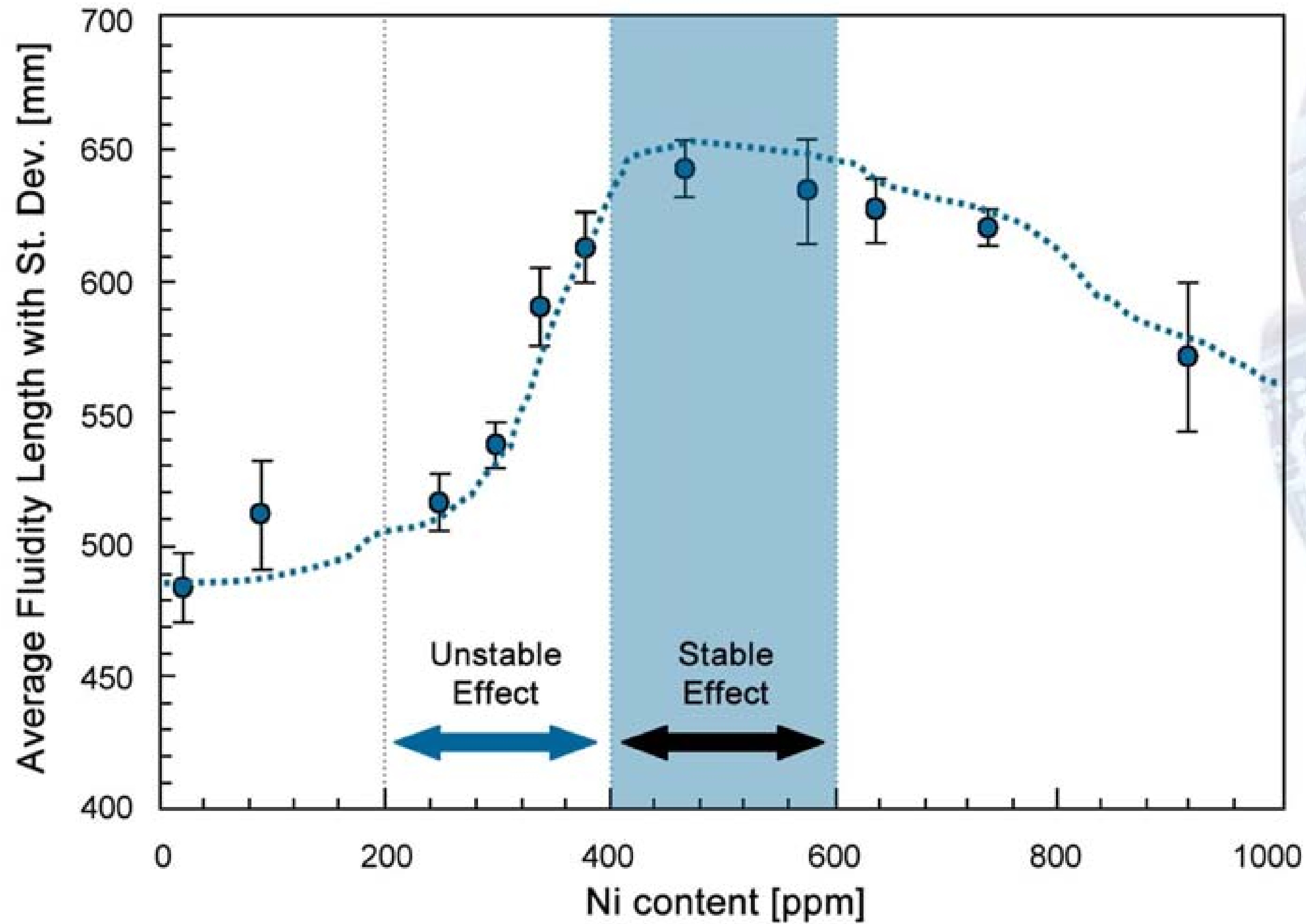
Cu_6Sn_5 IMC



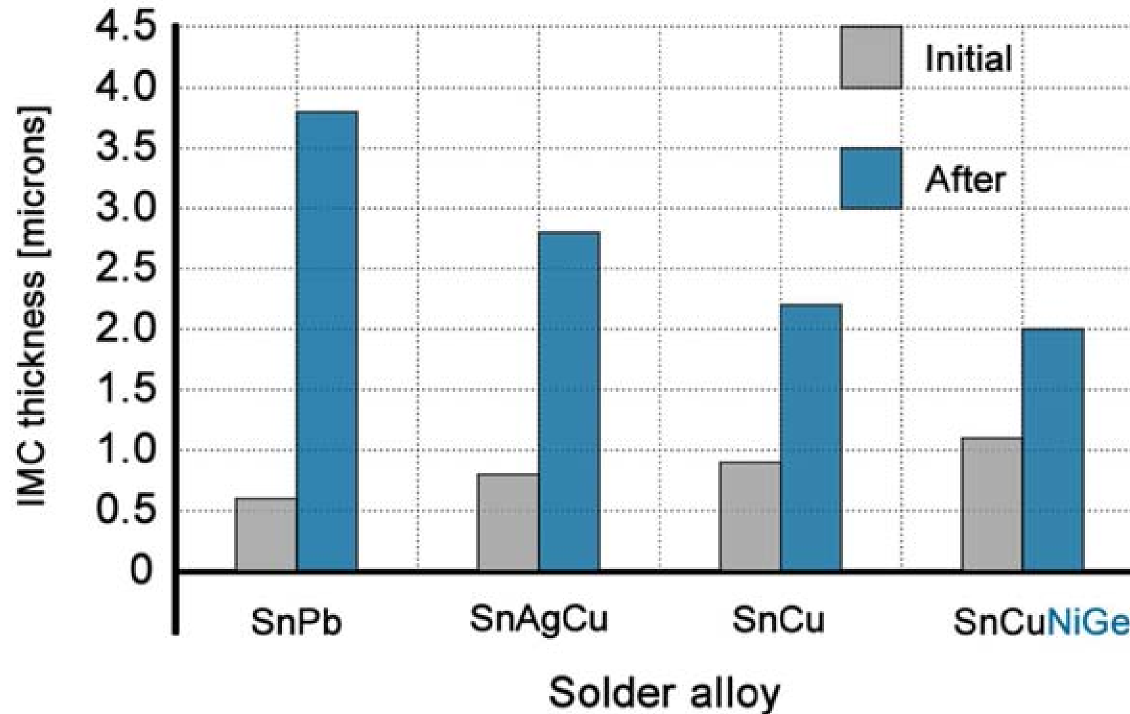
$(Cu,Ni)_6Sn_5$

at ~ 3 % Ni in $(Cu,Ni)_6Sn_5$

Fluidity and Ni Content

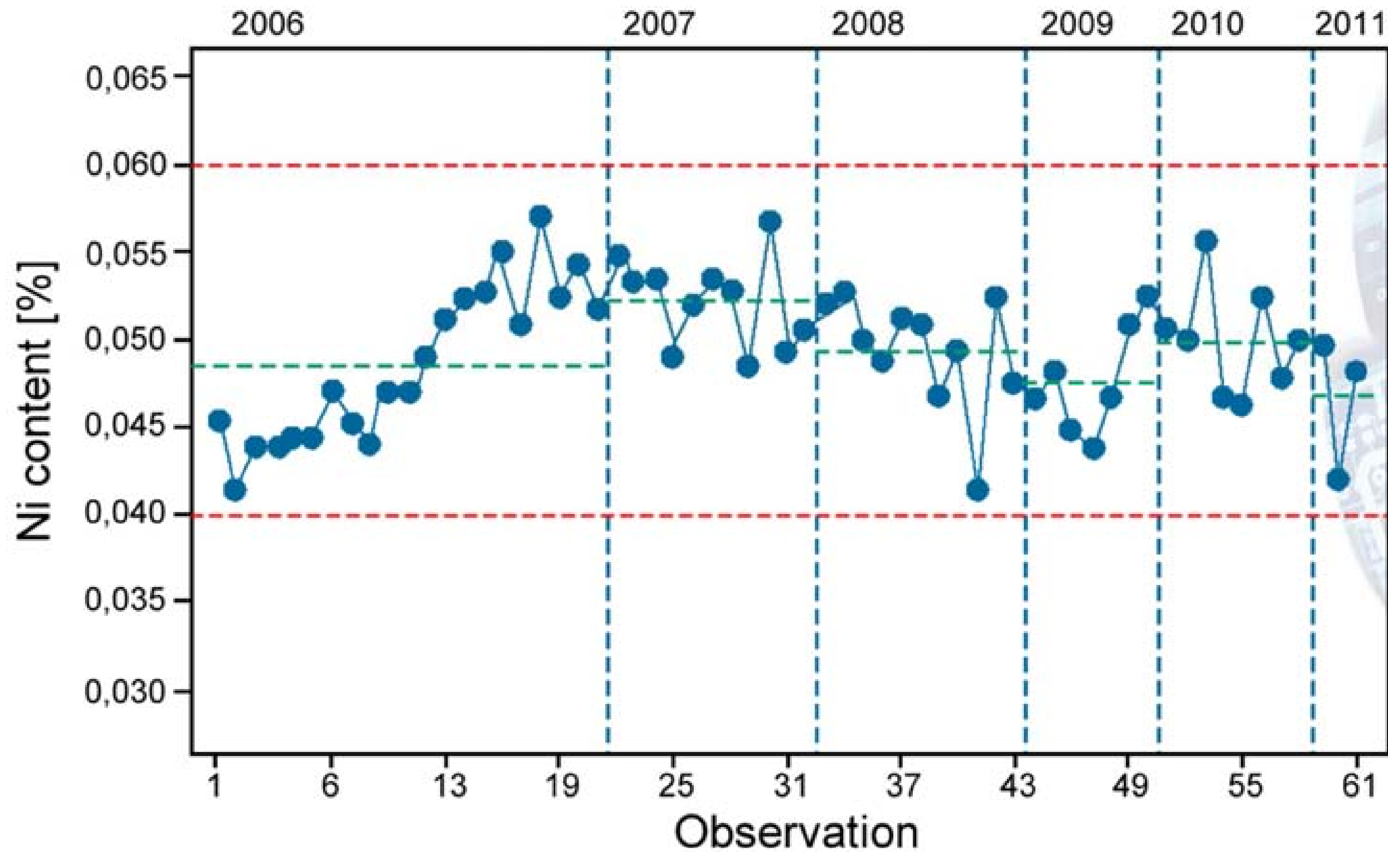


IMC growth



The Ni in the IMC has the effect of stabilizing the hexagonal crystal structure of the Cu_6Sn_5 and slowing down total IMC growth

Ni SPC-chart SN100C



Ni content is consistent over the years.

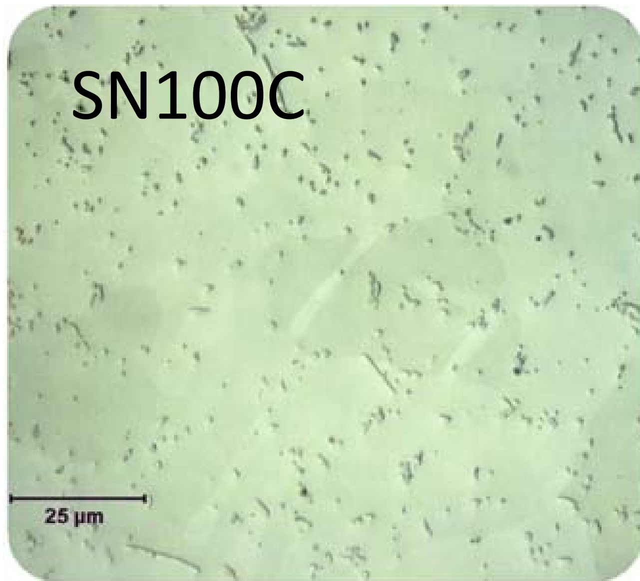
Ni-rich solder bars available.

High Ni content

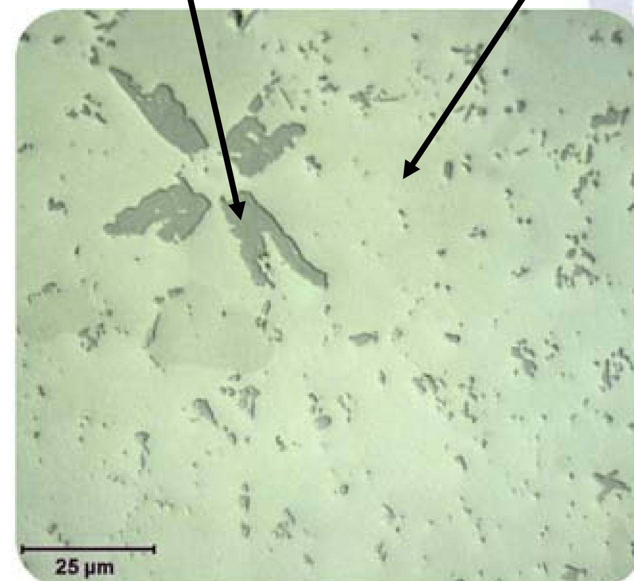
Uniform eutectic structure

Primary $(Cu,Ni)_6Sn_5$ Crystals

Eutectic between crystals

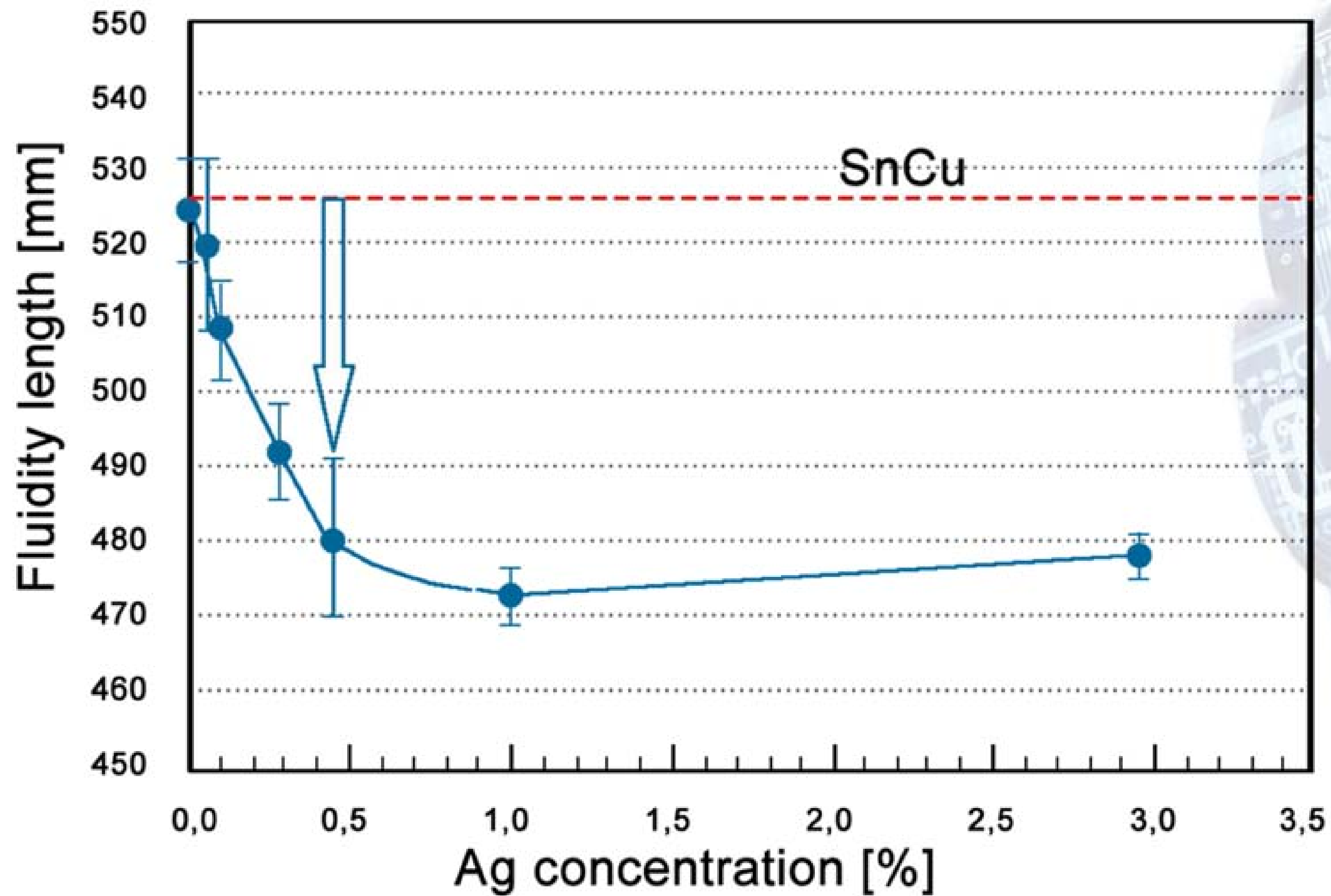


600 PPM



>1000 PPM

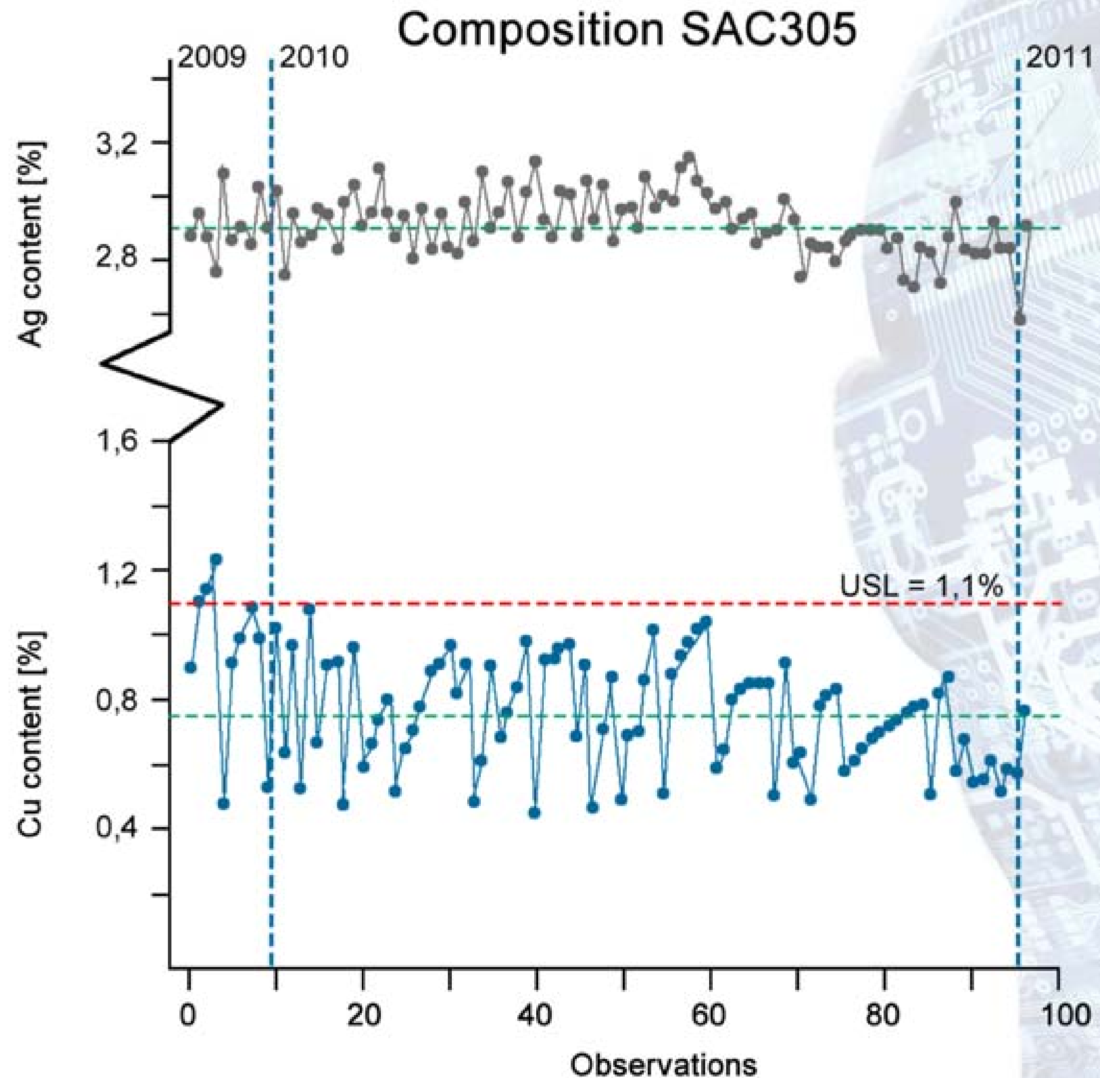
Impact of Ag on fluidity



SAC 305 elements contents

Selective soldering process

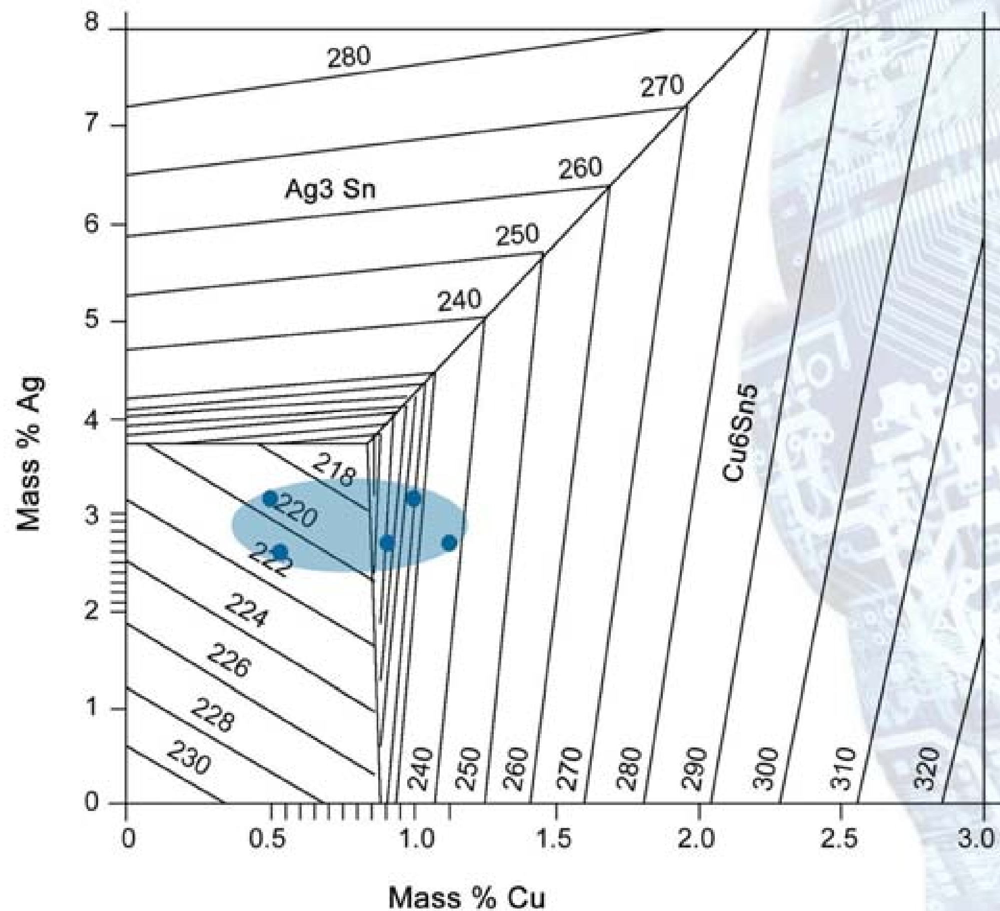
Cu drifts more due:
1. Leaching
2. SnAg or SAC bars



Silver/copper content in SAC305

Higher melting range:

- Fast solidification of solder
- Bridging
- Spikes



Germanium

Ge acts as an antioxidant and surface active agent.

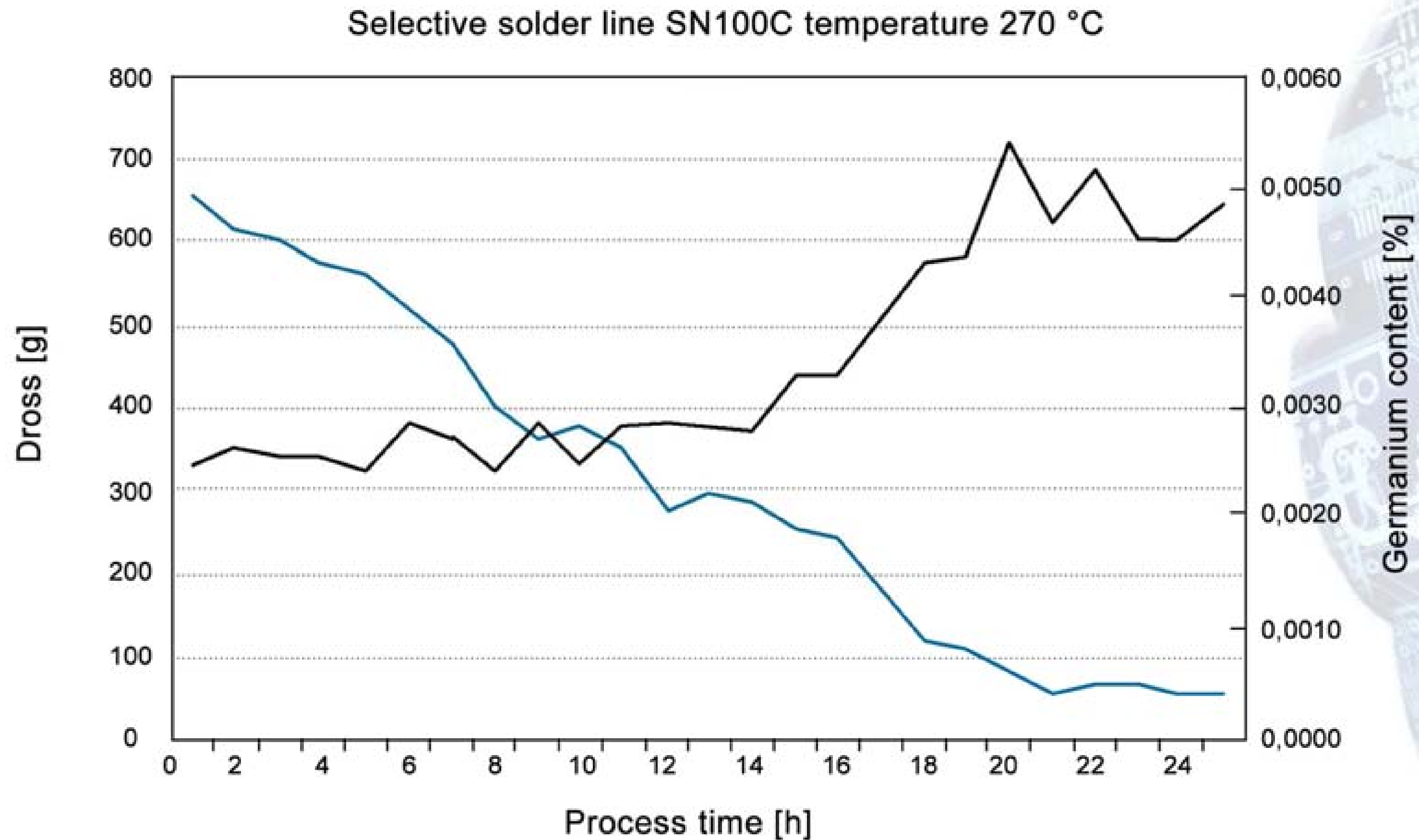
15 minutes ramp up to 340 °C - 30 minutes cooling

SnCuNi

SnCuNiGe

K Watling, A Chandler, K Nogita. A Dahle, University of Queensland

Dross and Germanium

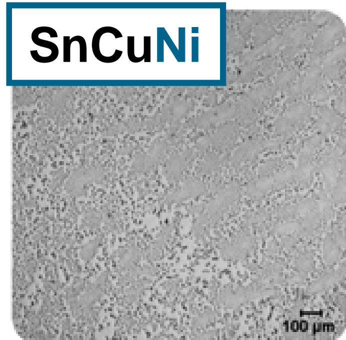


Less Ge results in more dross.

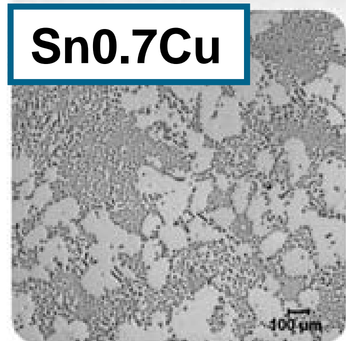
Impact of P

Phosphorus in lead-free solder (SAC) increases stainless steel erosion. P acts like a flux.
Adding P to SnCuNi destroys the beneficial effect of Ni.

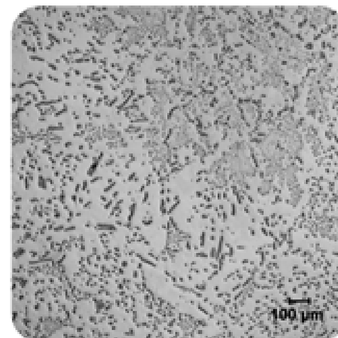
SnCuNi



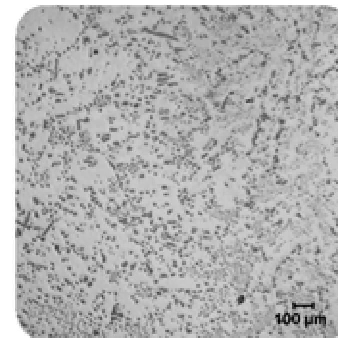
Sn0.7Cu



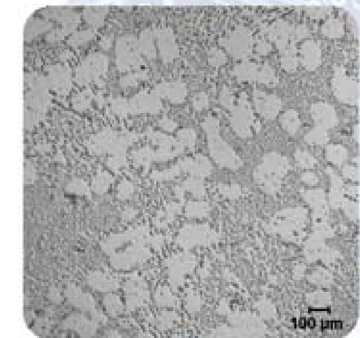
SnCuNi+0.007P



SnCuNi+0.02P

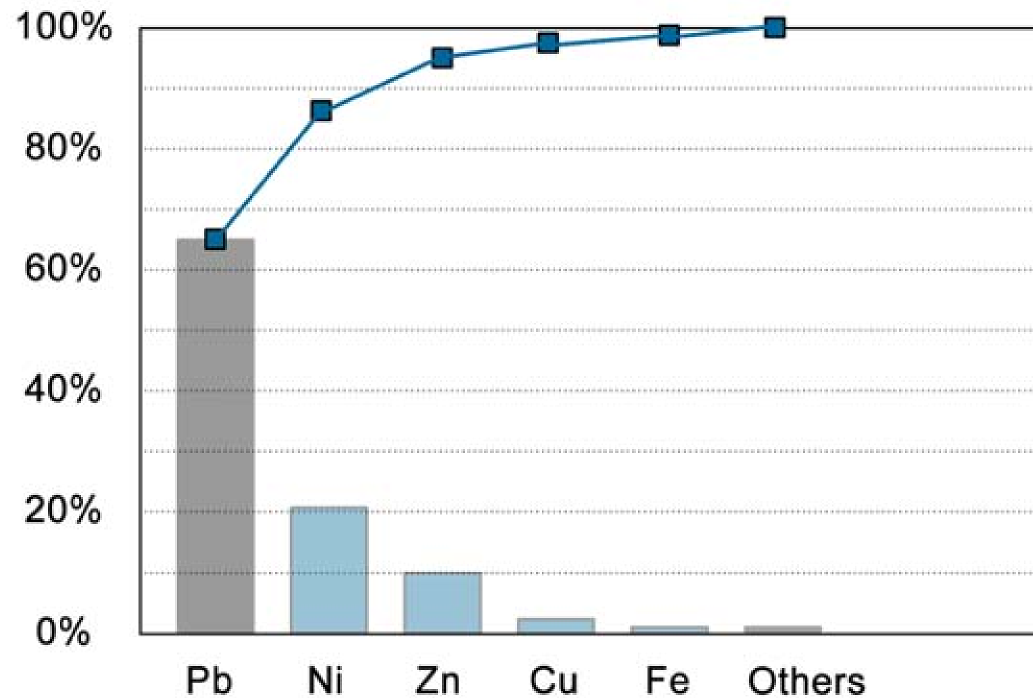


SnCuNi+0.06P



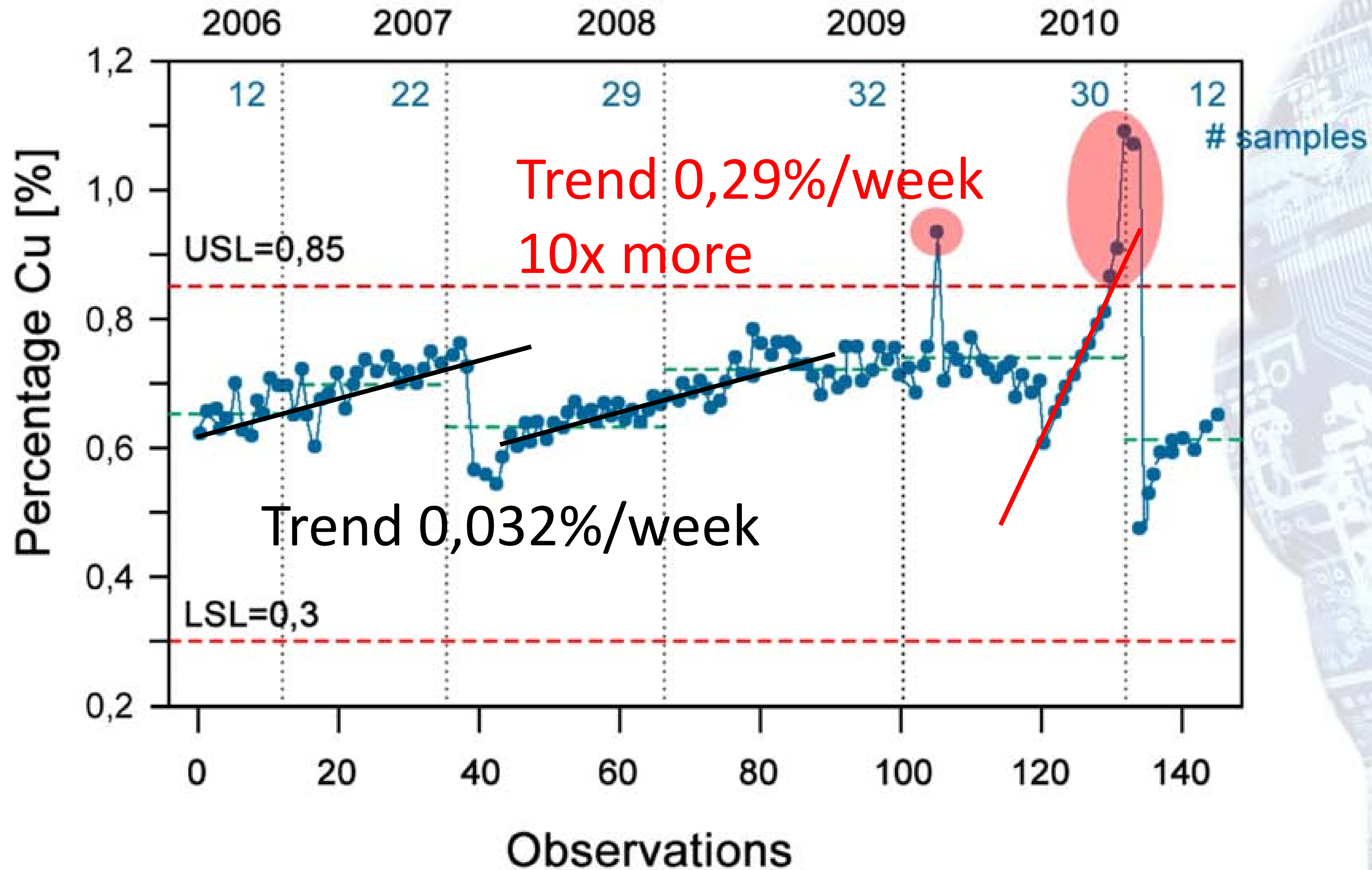
Similar – Ni benefit gone

SAC alloys out of spec



Number of Pb defects is decreasing
Ni is less critical

Sampling interval



Recommendations

IPC J-STD-001^{E} chapter 3.2.2. Solder Purity Maintenance:

"If contamination exceed limits, intervals between the analyses, replacement or replenishment **shall [N1D2D3]** be shortened."

"The frequency of analysis should be dertermined on the basis of historical data or montly analysis."

Dross

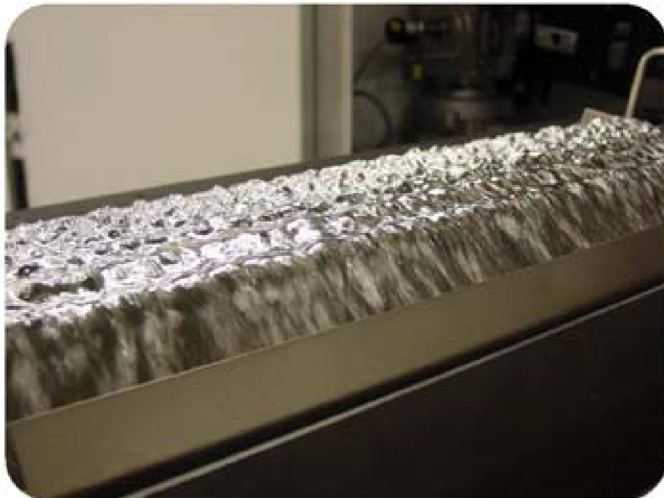
After running 20 hours (no maintenance)

Alloy	Time [h]	Dross [kg]	Rate [kg/h]
Sn3.8Ag0.7Cu ref.	52	10.5	0.202
Sn3.8Ag0.7CuCoGe	70	2.73	0.039
Sn0.3Ag0.7CuNiGe	20	0.78	0.039

Solder (wave) continuous running. Solder temperature 260 C.

Minimize dross

- Use Nitrogen blanket
- Reduce solder fall height
- Ge tablets
- Wave former



SnPb wave versus selective

Tin lead solder - wave versus selective				
	Wave solder line		Selective solder line	
Element	Average [%]	Standard deviation [%]	Average [%]	Standard deviation [%]
Sn	62,489	0,362	62,565	0,347
Pb	37,454	0,365	37,258	0,348
Ni	0,0045	0,0006	0,0201	0,0034
Cu	0,0172	0,0025	0,0082	0,0018
Ag	0,0040	0,0008	0,0358	0,0032
Au	0,0070	0,0006	0,0221	0,0030

Automotive line (identical products)

One year average scores

Periodic table

Halogens

Anti-oxidants

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 *	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 **Ac	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	110 Unn								

RoHS

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu

Rare Earth elements
(Vitamins)

Conclusions:

- Lead-free soldering requires more alloy analyses.
- Copper contents in lead-free solder alloys should be monitored on a frequently basis. (Minimal 12 x /year for selective soldering)
- Lead impurities are decreasing in lead-free alloys.
- Metal erosion (solder pot parts) is hard to identify by solder analysis. Check during maintenance.

Acknowledgement

- Balver Lab
- Nihon Superior