NIHON SUPERIOR

"Lessons Learned from Seven Years Experience of Lead Free Wave Soldering"

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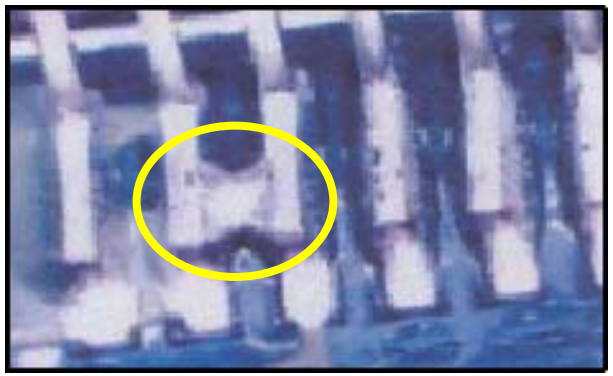
NIHON SUPERIOR NSe LEAD FREE e-SOLDER

Agenda

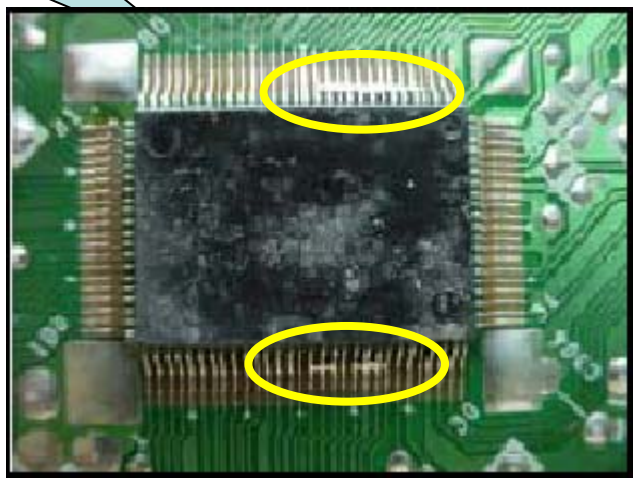
- **Introduction**
  - **Example of problems**
  - **A lead-free wave soldering learning curve**
- **Stage 1: Selection of alloy**
- **Stage 2: Change of alloy**
- **Stage 3: Optimization of process**
- **Stage 4: Modification of machine**
- **Stage 5: Modification of design**
- **Summary**
- **Conclusion**

Bridging problems

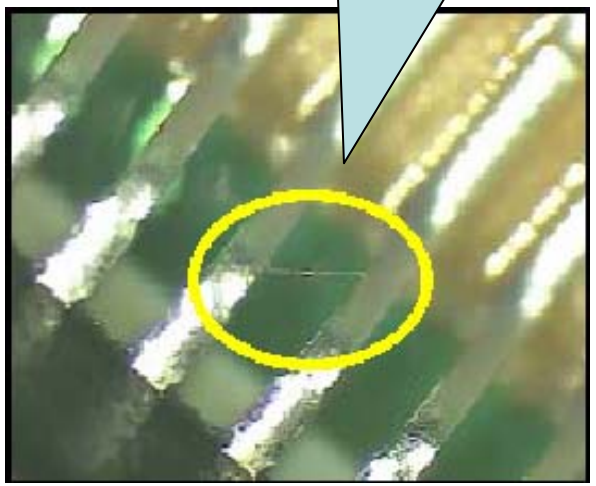
Bridge on QFP pins



Bridge on QFP pins

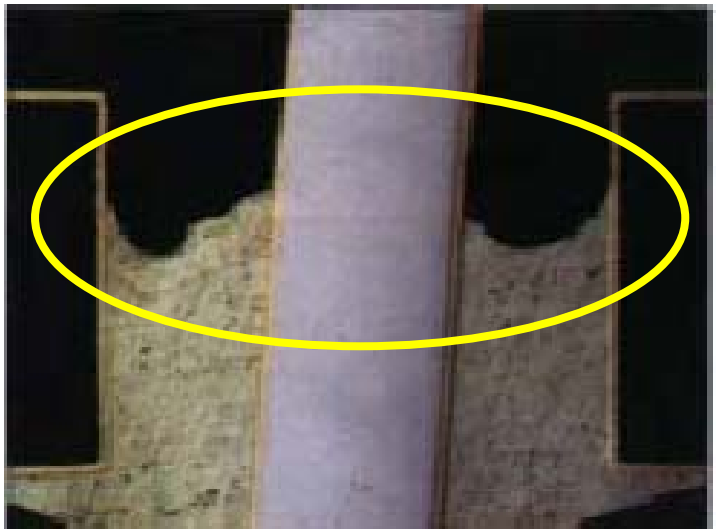


Micro-bridge

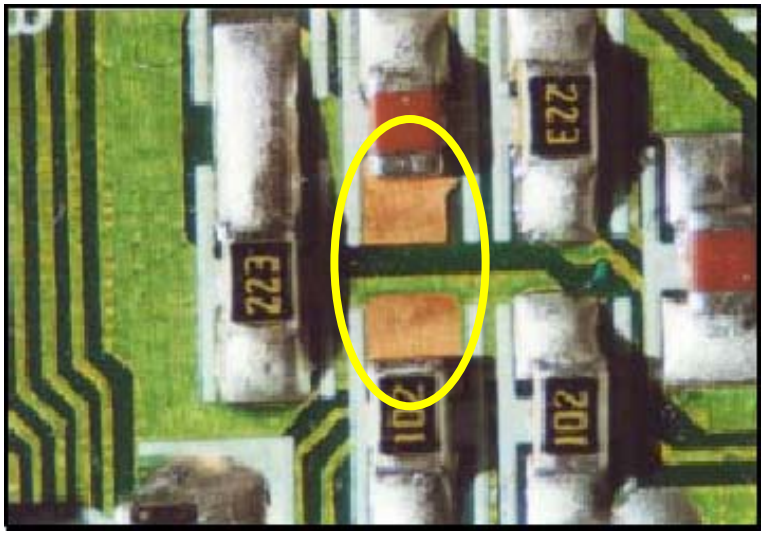


Wetting problems

Insufficient though-hole penetration

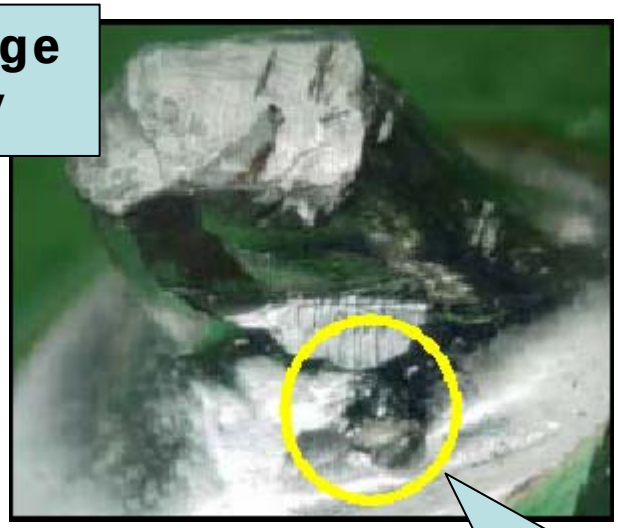


Solder skip Non-wetting



Other problems

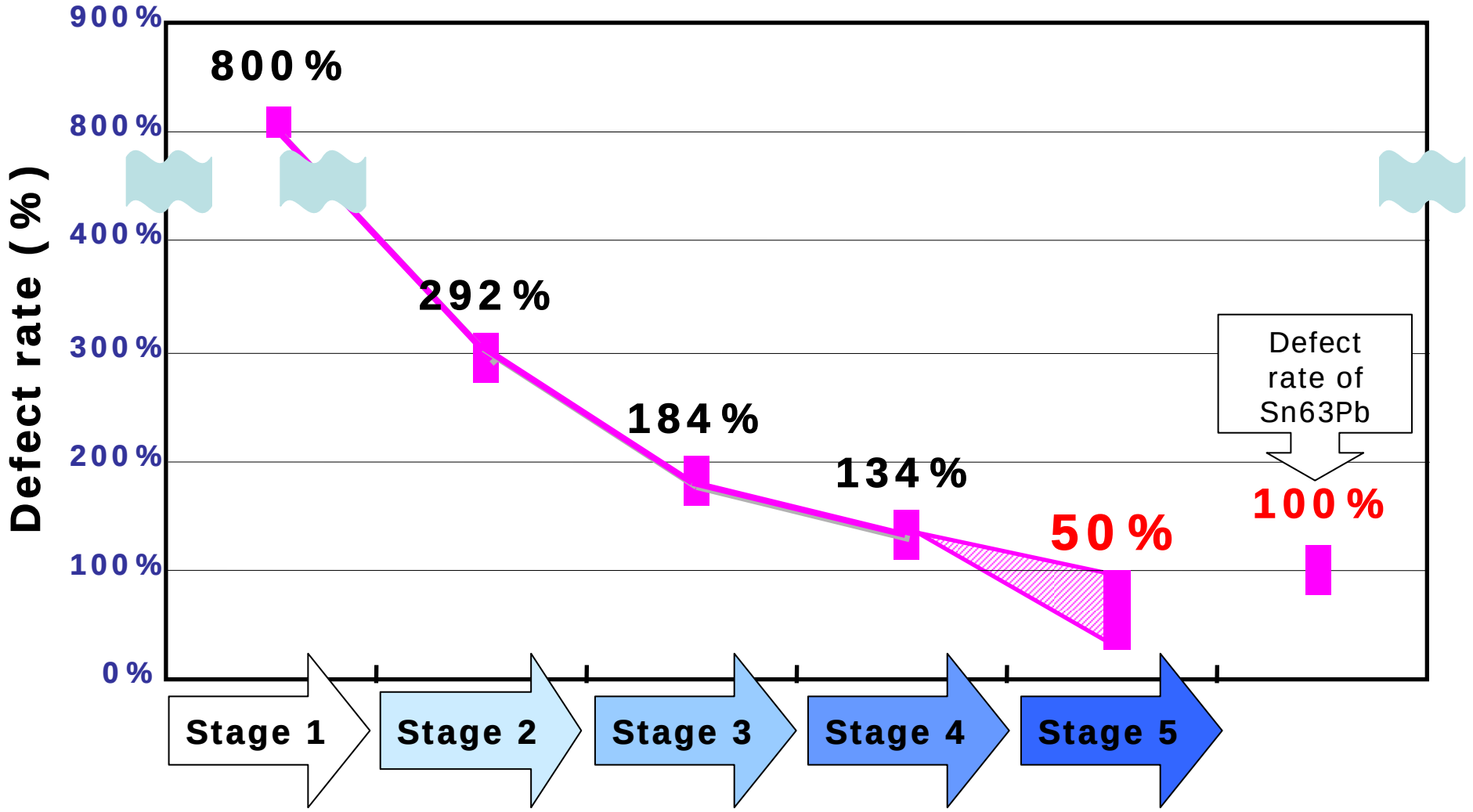
Shrinkage cavity



Blow hole

Oxidation and generation of dross

A lead-free wave soldering learning curve

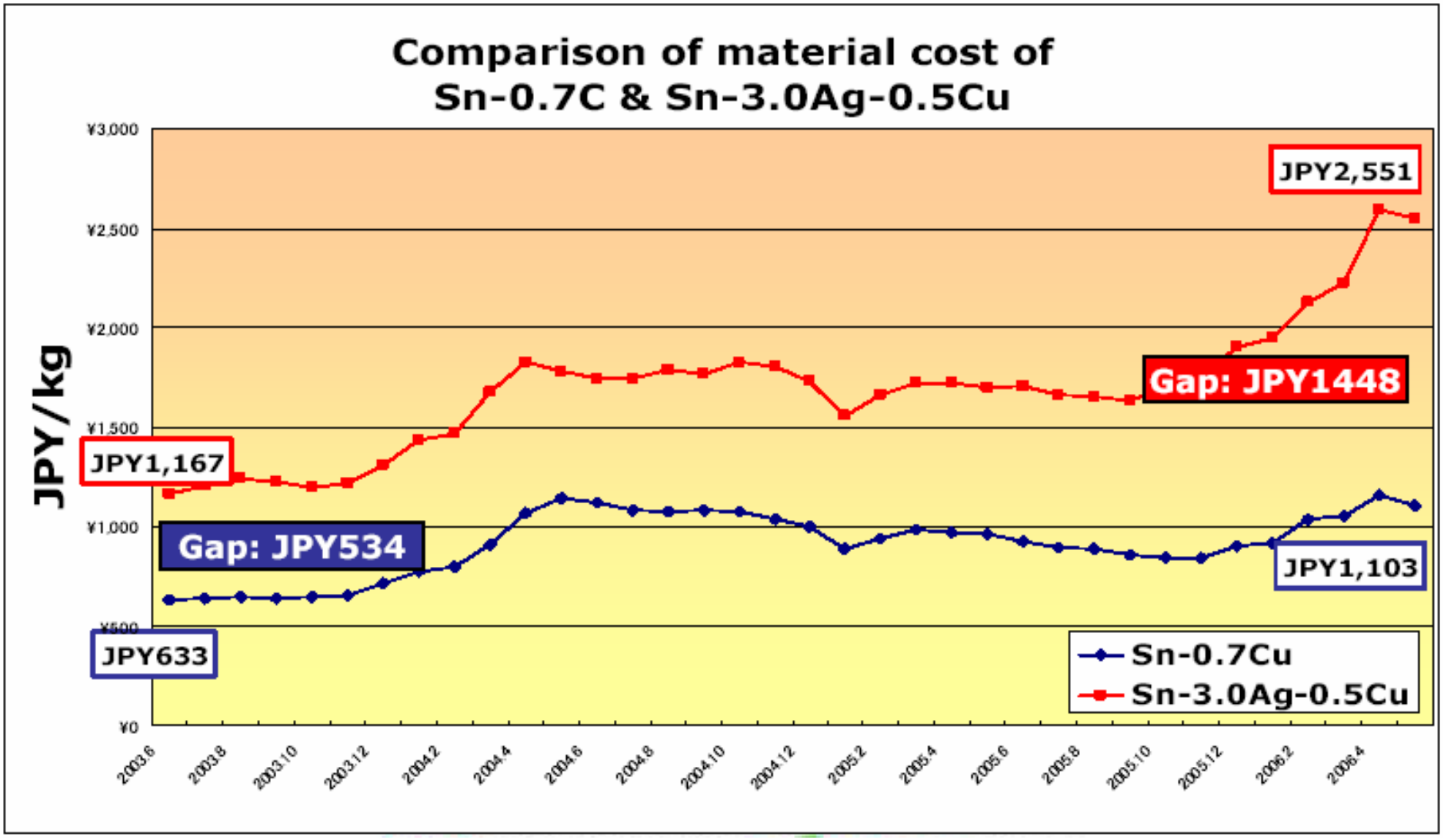


Stage 1: Selection of Sn-Cu

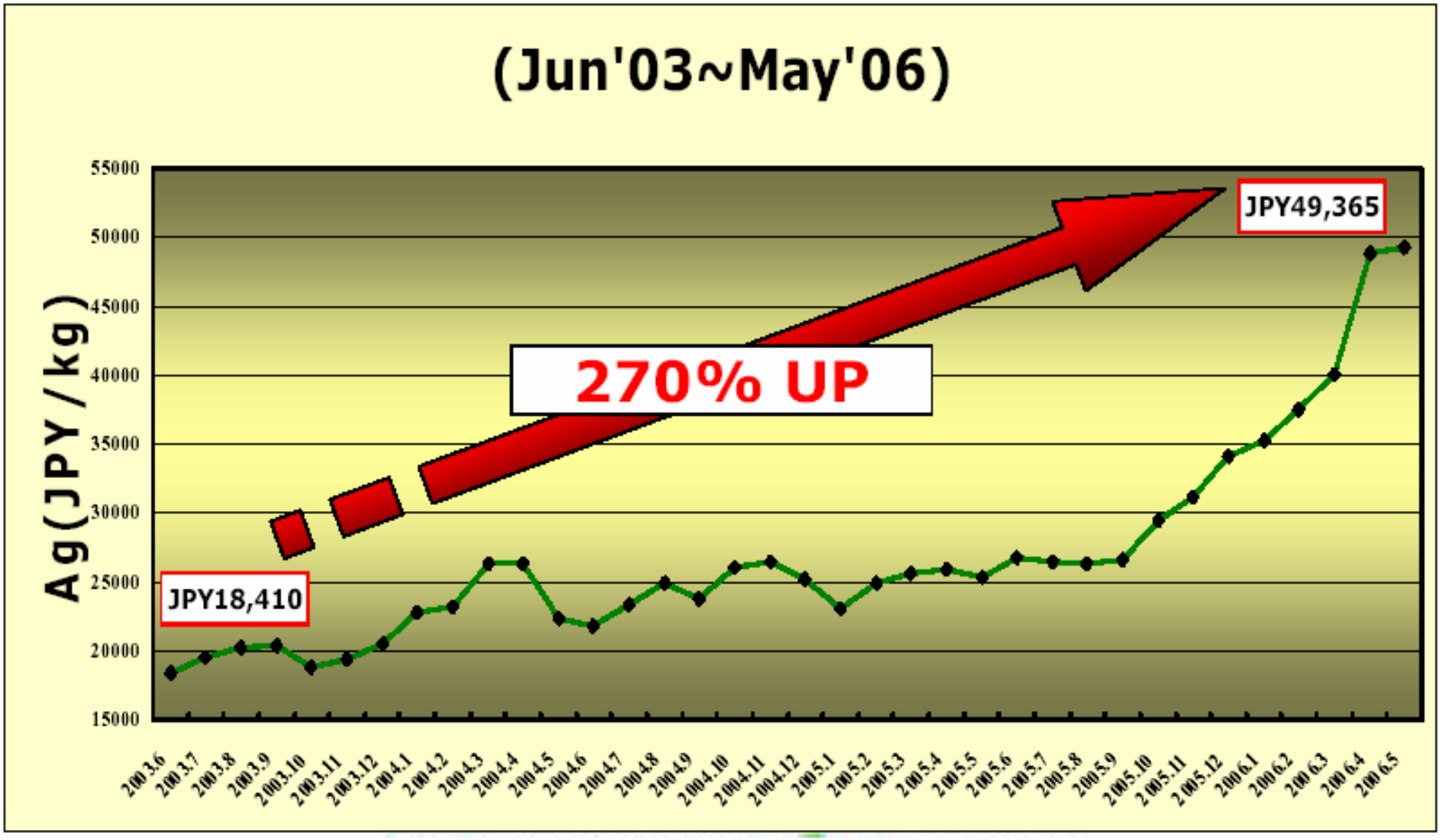
Sn-0.7Cu solder was chosen at first.
The reasons are…

- **Stability of material cost (Low cost)**
- **Possibly the simplest alloy**
- **Eutectic alloy**

Comparison of material cost

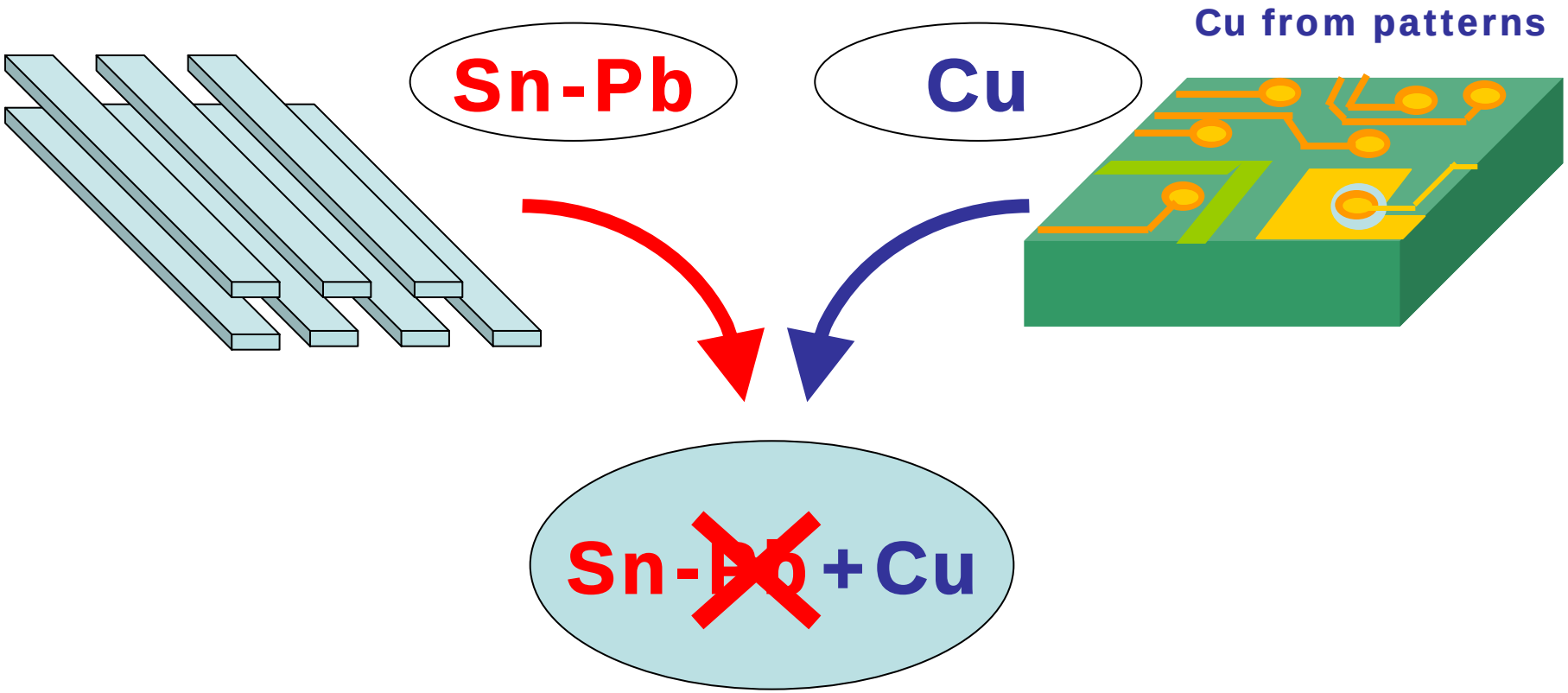


Market price of Silver



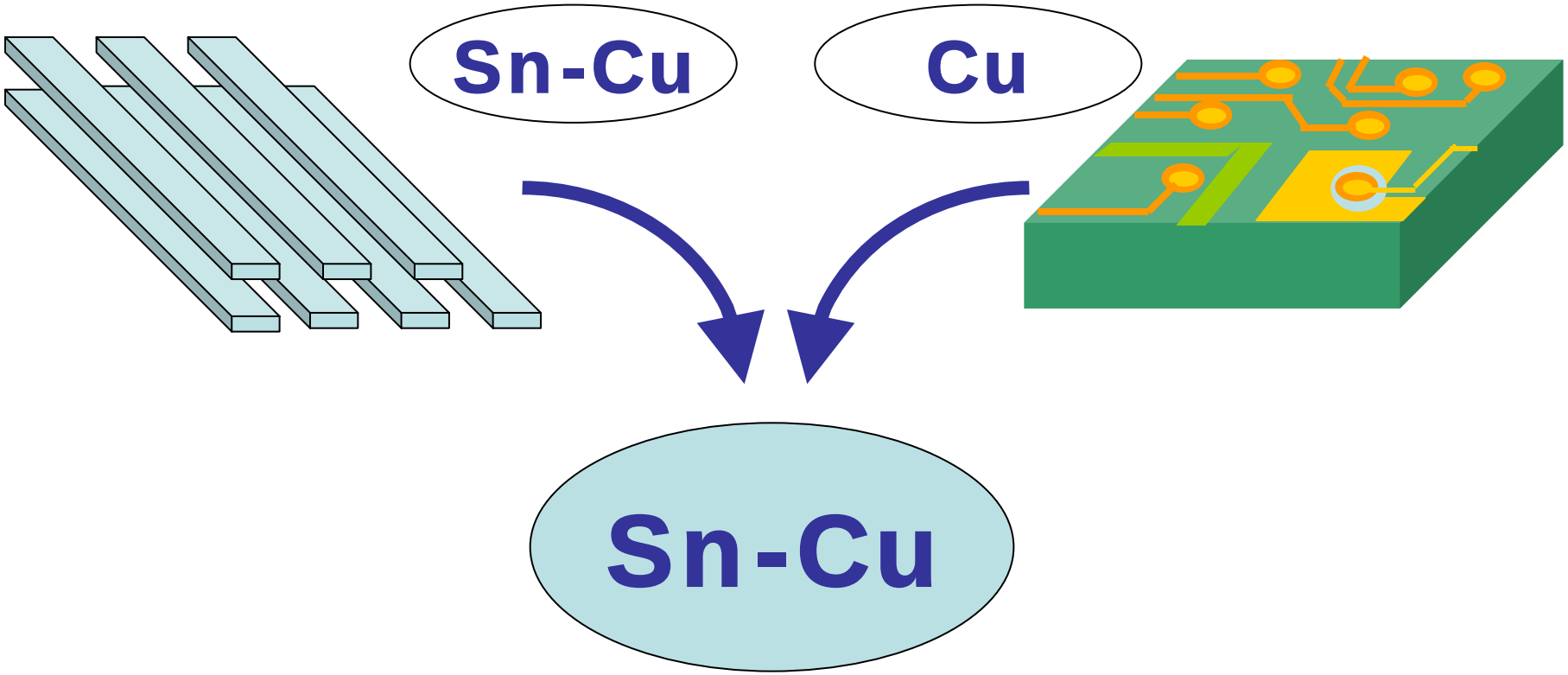
Typical permissible Cu level

Typically permissible Cu level in Sn-37Pb is about 0.3%. (Cu is impurity for Sn-Pb)



Possibly the simplest alloy

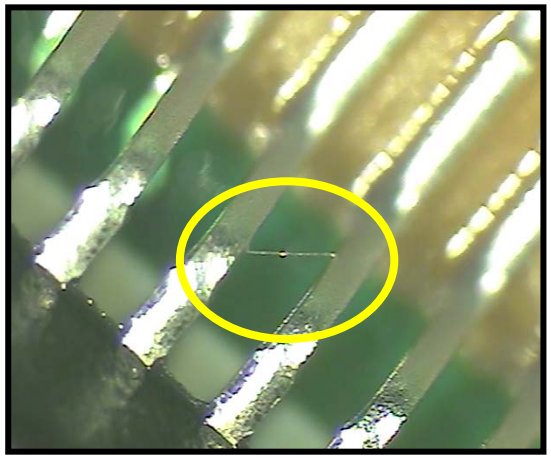
Sn-Cu is possibly the simplest alloy (as long as copper is used for PCB)

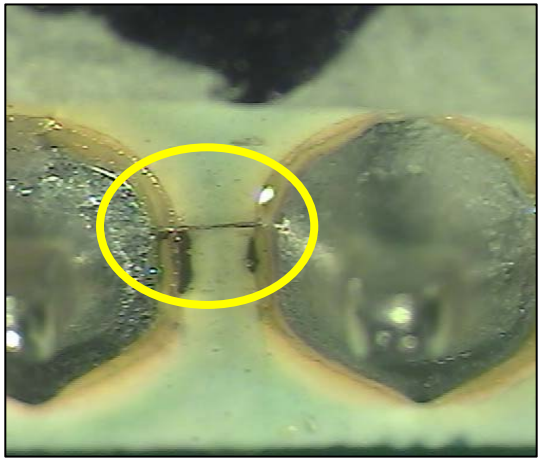


Permissible Cu level

Comparison of permissible Cu level

Solder	Typical permissible Cu level
SN100C (Sn-0.7Cu-Ni-Ge)	0.85 % <
Sn-Pb	0.3 % <





Eutectic alloy

Unlike one of the most widely promoted lead-free solders, Sn-3.0Ag-0.5Cu,

Sn-0.7Cu

- **Is a eutectic alloy**
- **Can be made to behave as a eutectic**

Alloy	Solidus	Liquidus
Sn-0.7Cu	227C	227C
Sn-3.0Ag-0.5Cu	218C	219C

Benefits of eutectic alloys

Benefits of eutectic are…

“Less segregation and less shrinkage”

The benefits of eutectic include…

“Smooth bright fillets”

“Fine uniform microstructure”

“Lower incidence of shrinkage defects”

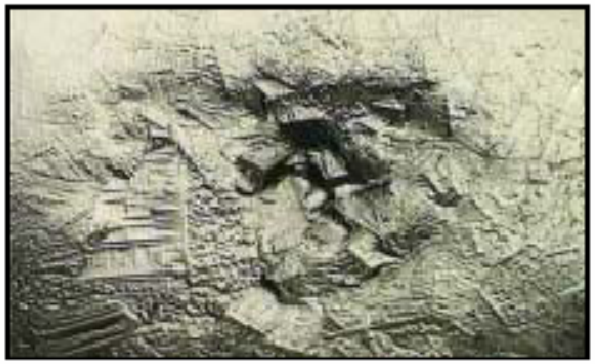
“Less segregation of contaminants”

Stages in the solidification of a non-eutectic lead-free solder

1. Liquid

2. Tin dendrites starting to form

3. Liquid starting to shrink away exposing structure of tin dendrites



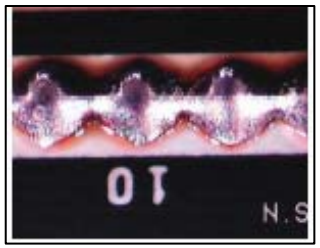
4. Completely solidified

5. Shrinkage continuing after soldification

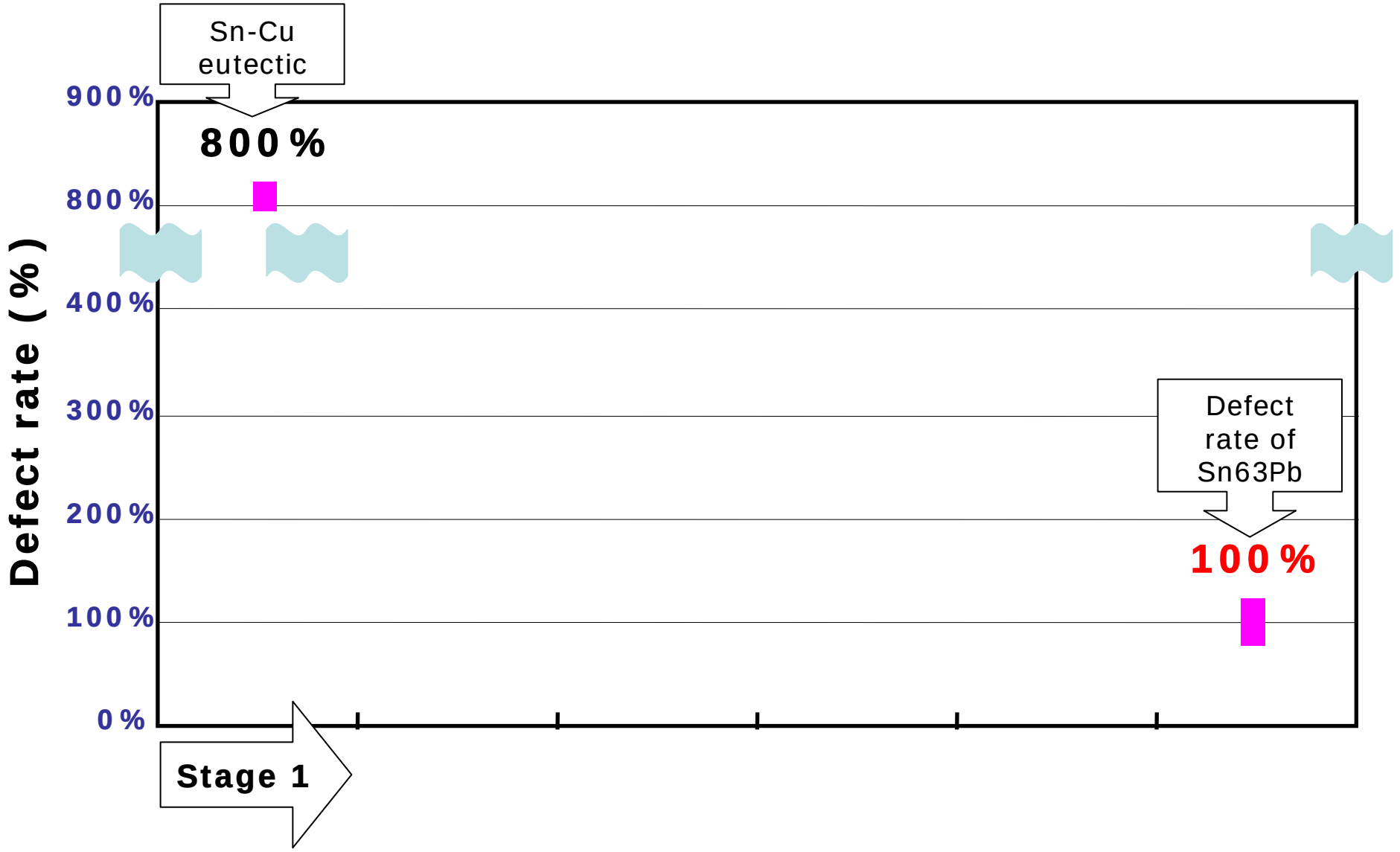
Problems of Sn-0.7Cu

Although Sn-0.7Cu has many advantages as a lead-free solder, when it was tried in wave soldering, it was found that it suffered from problems.

- **Grainy joints, which often cracked making inspection difficult**
- **High incidence of bridges**
- **Heavy dross generation**



A lead-free wave soldering learning curve



Stage 2: Change of alloy

Those problems were addressed by switching to Sn-Cu-Ni+Ge alloy, SN100C.

Benefits of addition of Ni and Ge…

- **Smooth and bright joints**
- **Reduction of incidence of bridges**
- **Reduction of dross generation**

Grainy surface

**Compared to Sn-37Pb,
surface of Sn-0.7Cu is so grainy that
inspection procedure would need change.**

Sn-37Pb

Sn-0.7Cu

Surface of Sn-Cu-Ni+Ge

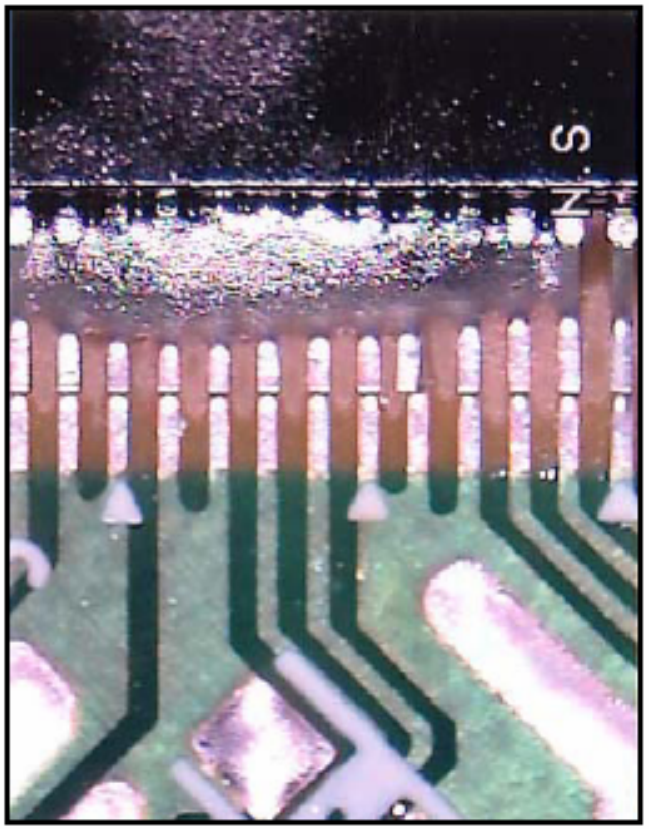
Trace addition of Ni modifies grainy surface of Sn-0.7Cu. Sn-Cu-Ni+Ge just looks like surface of 63Sn-Pb.

Sn-37Pb

SN100C

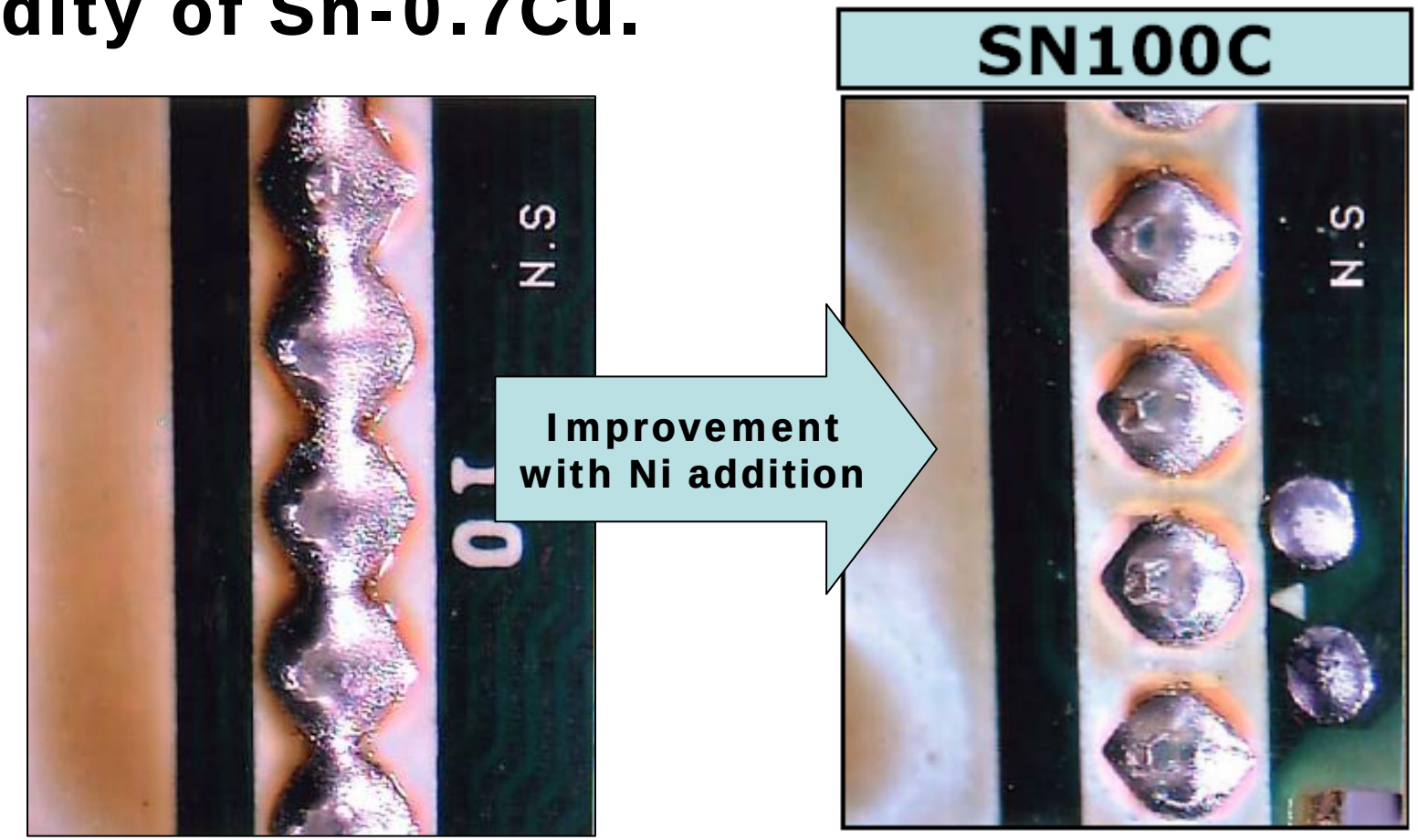
Bridging

Due to its bad fluidity,
Sn-0.7Cu causes bridges.

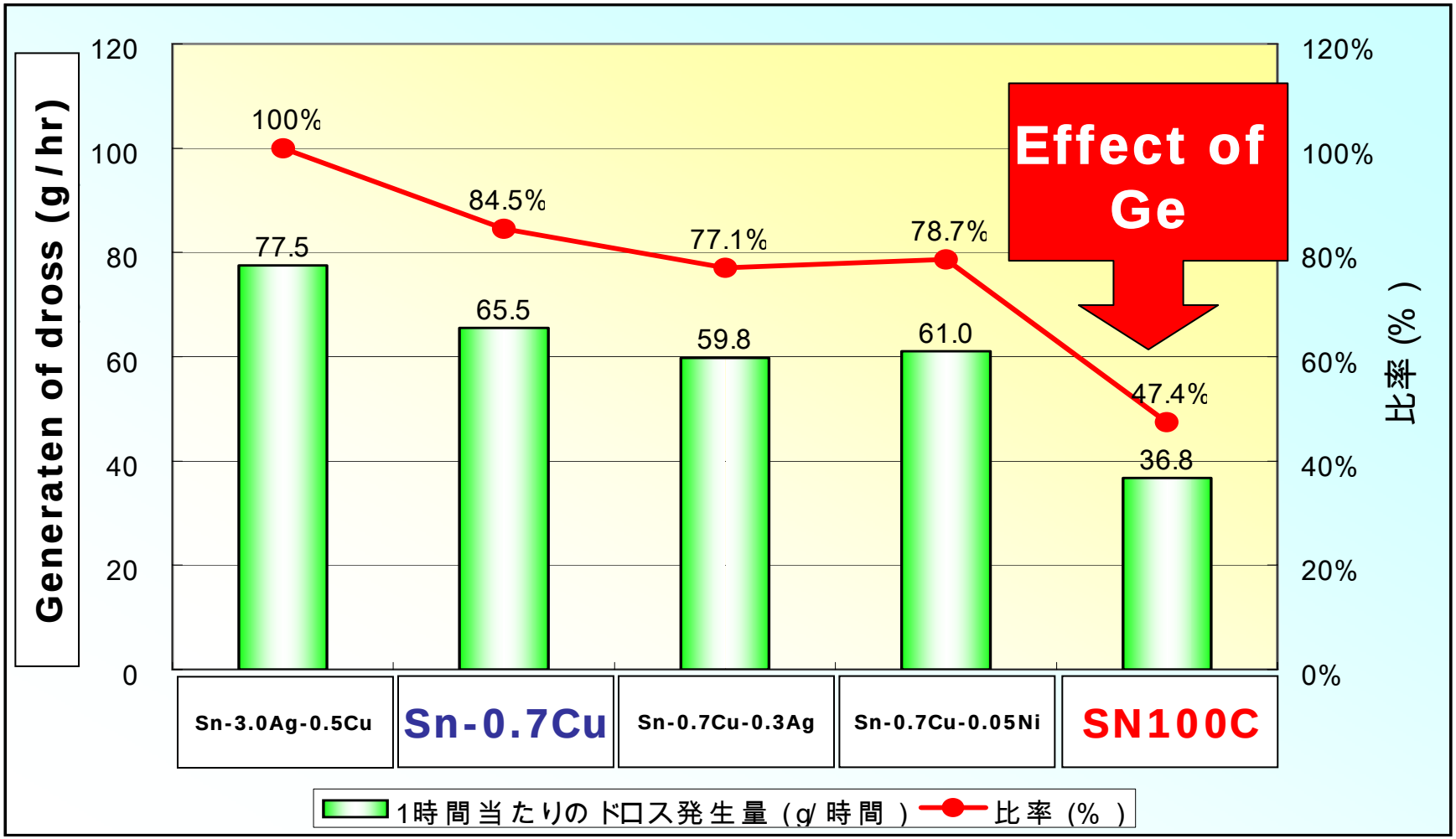


Fluidity of Sn-Cu-Ni+Ge

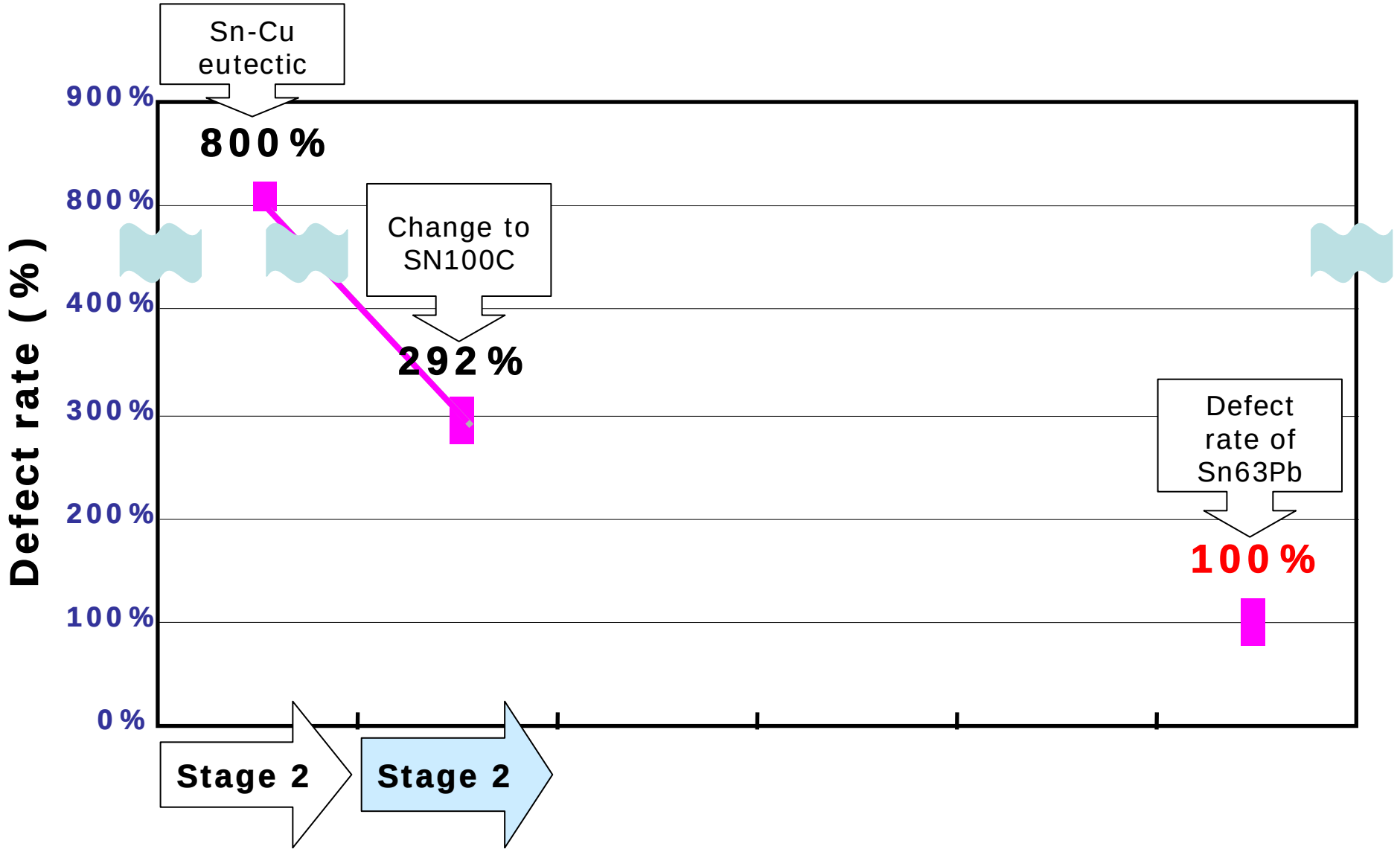
Trace addition of Ni improves fluidity of Sn-0.7Cu.



Reduction of dross



A lead-free wave soldering learning curve

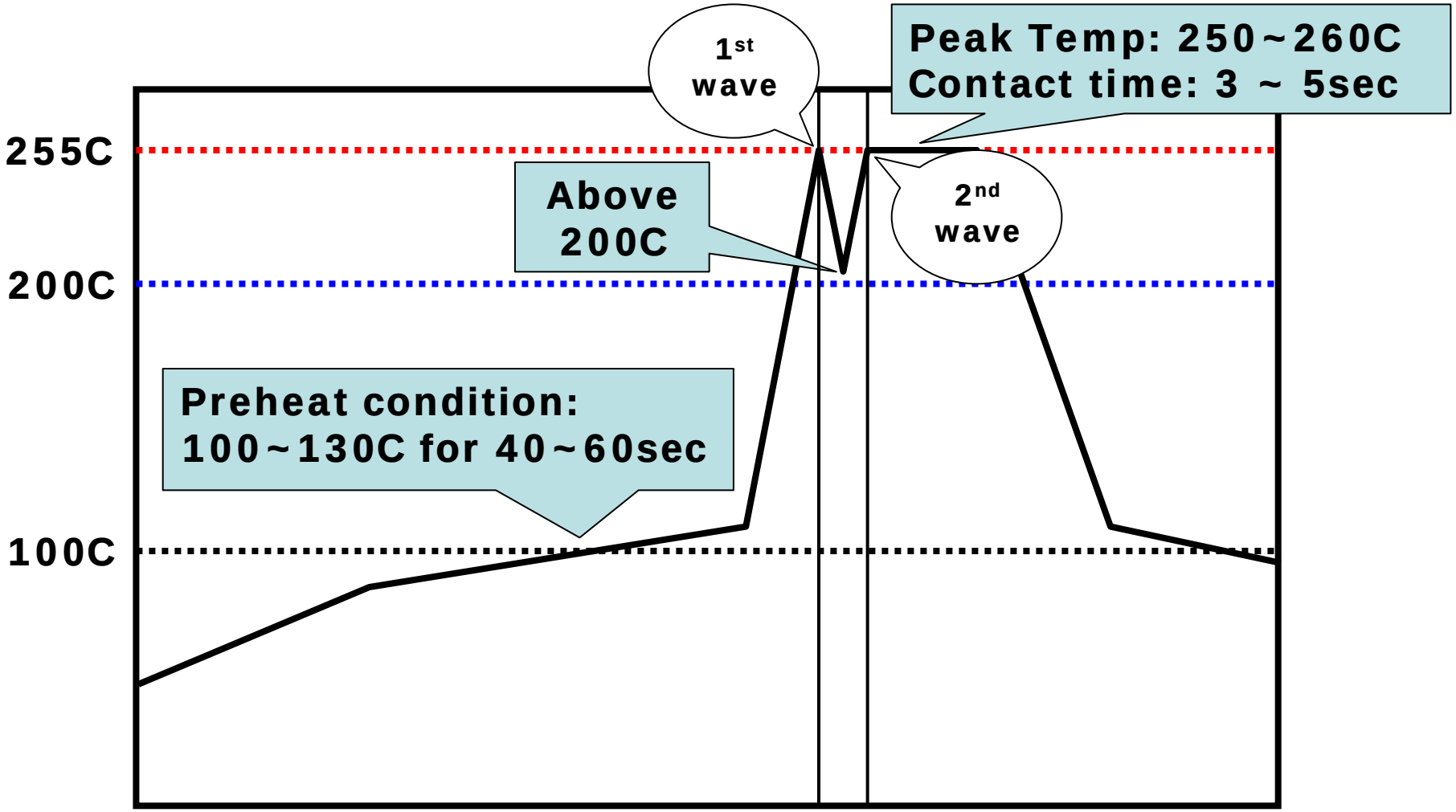


Stage 3: Optimization

Even after the switch to SN100C, the defect rate was still 300%.
Attention was needed to the following points.

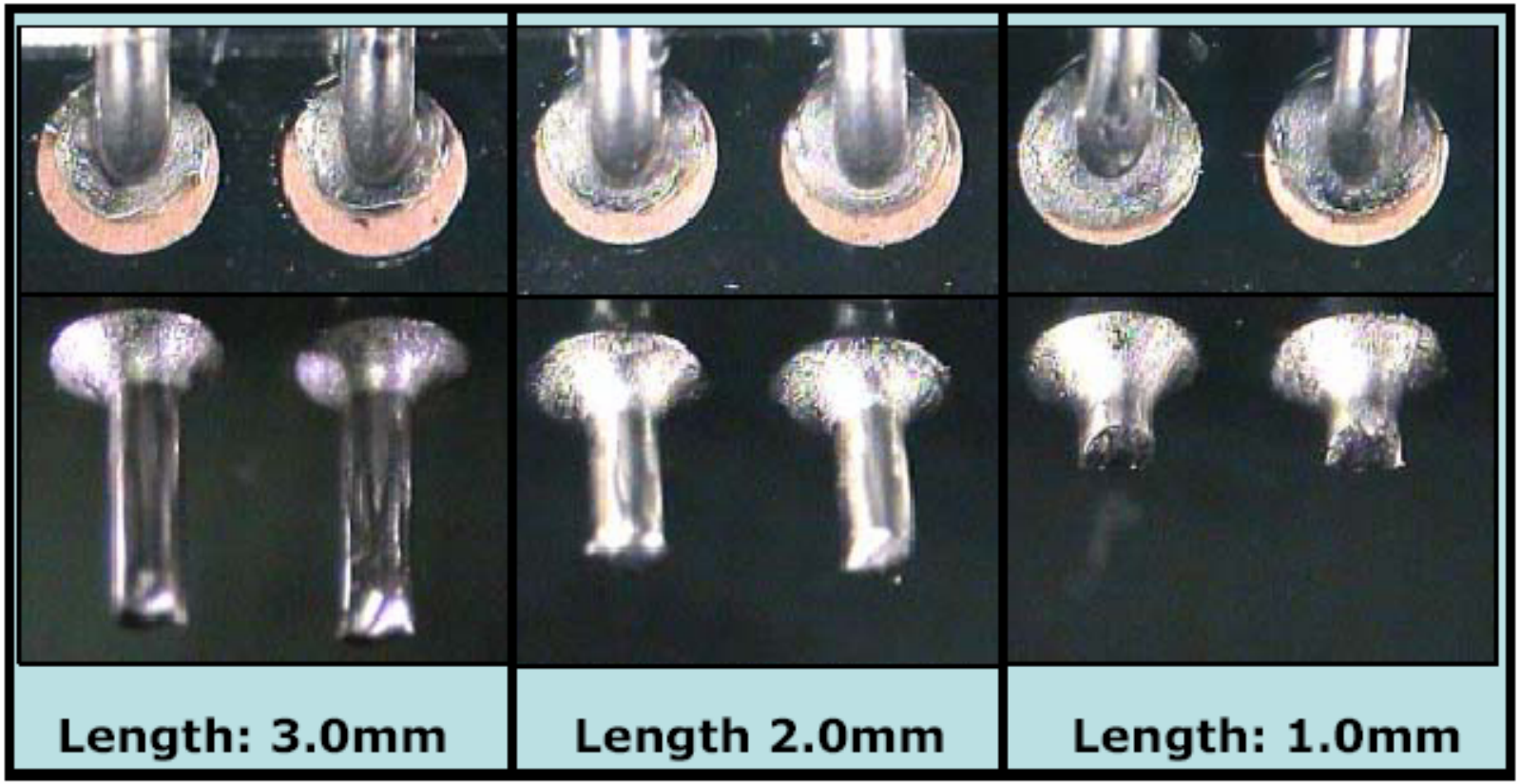
- **Thermal profile**
- **Length of termination**
- **Contact time**
- **Contact depth**

Typical thermal profile for SN100C

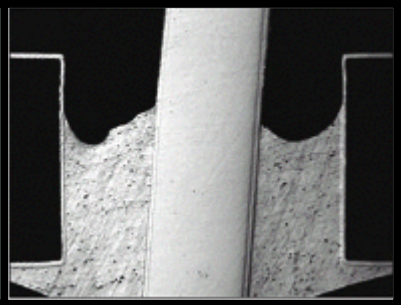
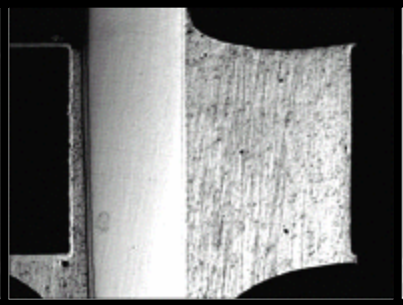
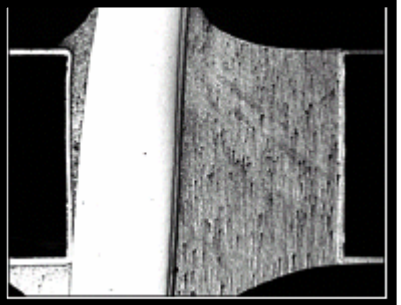
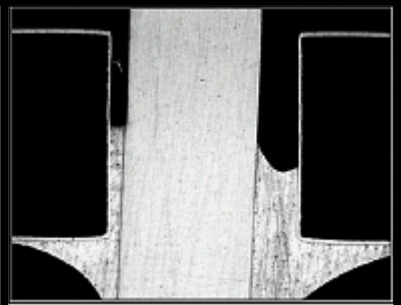
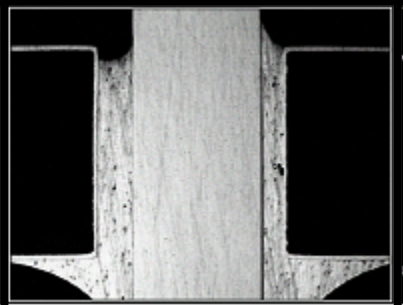


Length of termination

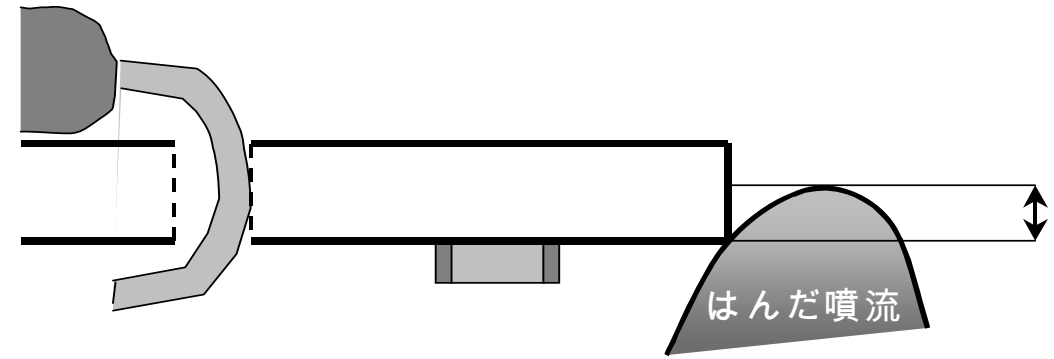
DIA: 1.0mm
Land width: 0.45mm



Contact time

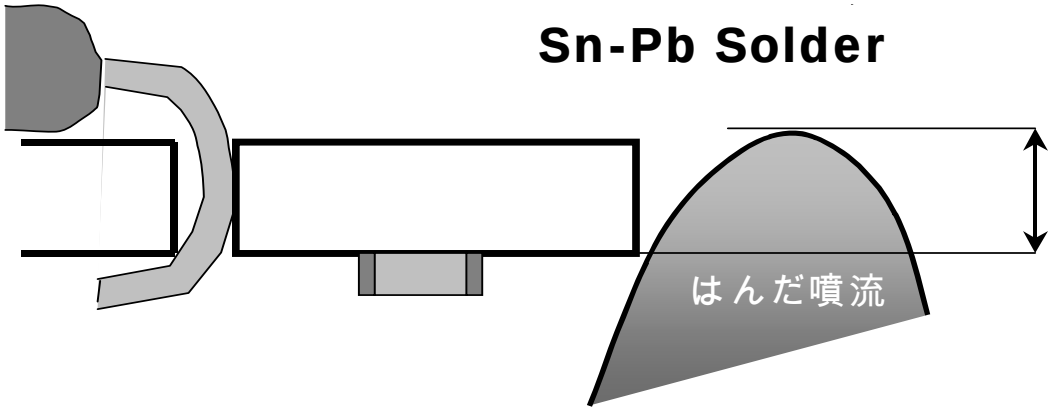
	1.4mm/min	1.1mm/min	0.8mm/min
Through hole DIA: 2.0mm Lead DIA: 1.4mm			
Through hole DIA: 1.4mm Lead DIA: 1.0mm			

Immersion depth



As deep as
½ of board thickness

Sn-Pb Solder

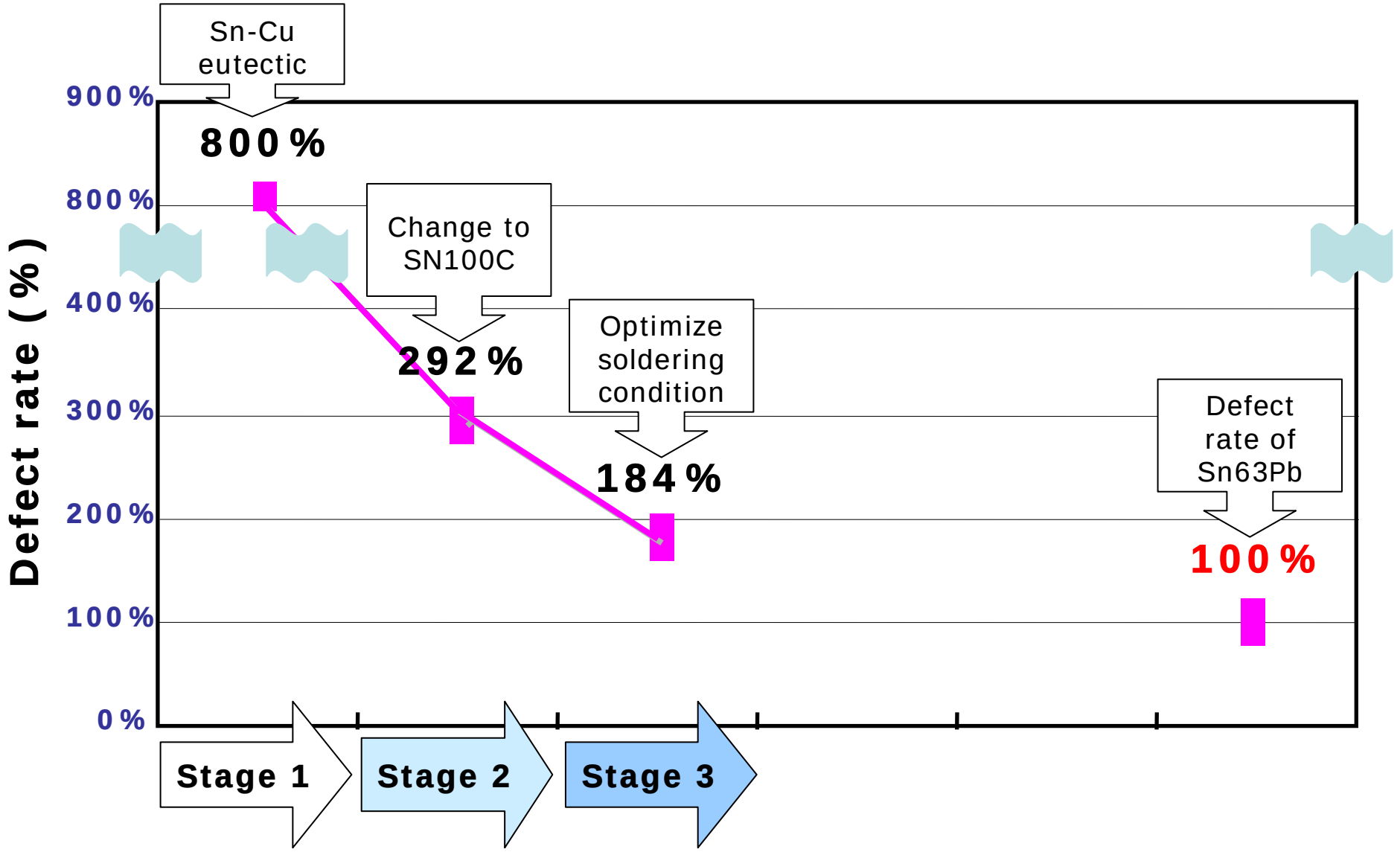


As deep as
board thickness

Lead-free solder

This is possible because surface tension of lead-free solder means that there is no tendency for the solder to spill onto the topside of the board

A lead-free wave soldering learning curve

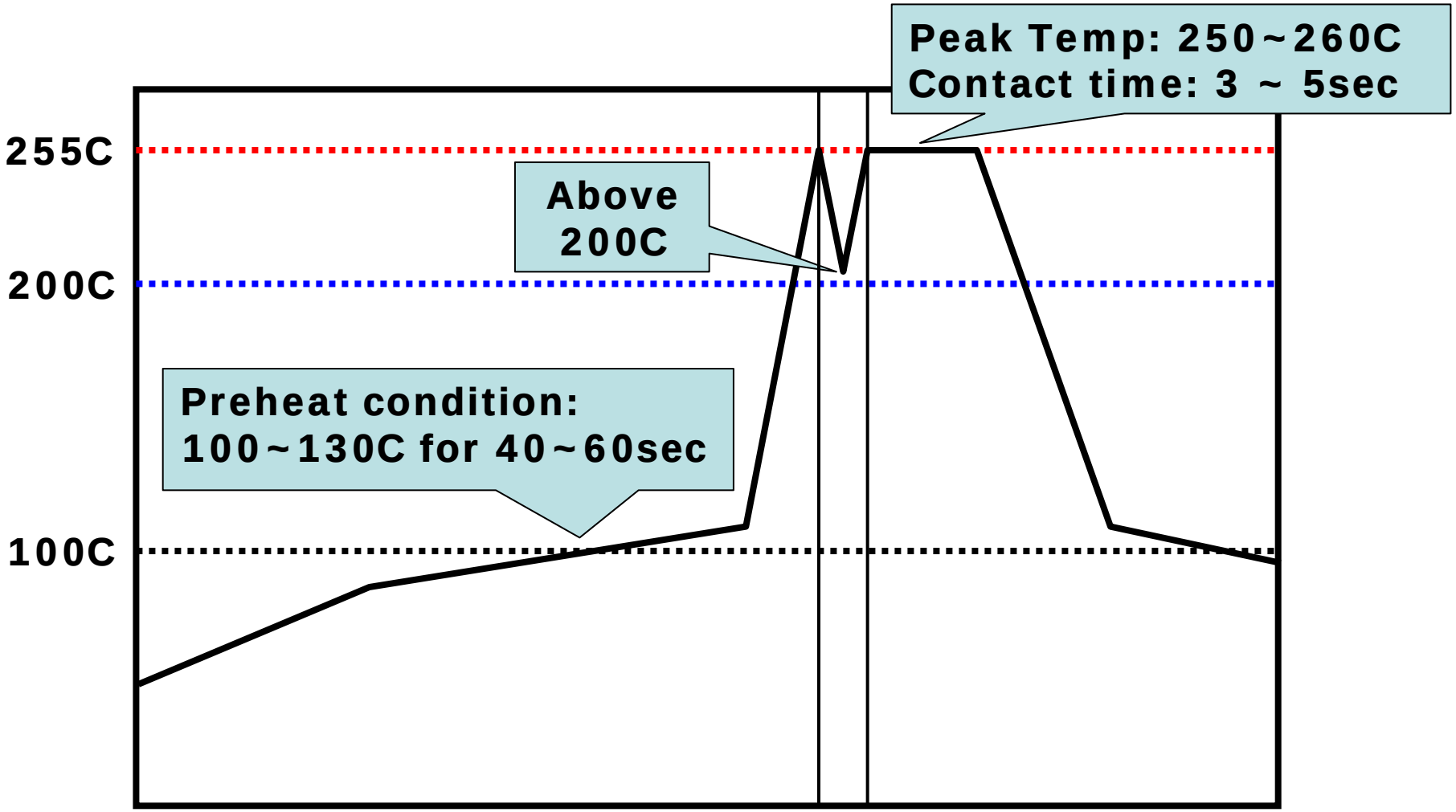


Stage 4: Modification of machine

Even after stage 3, the defect rate was still 184%.
Now attention was needed to modification of a wave soldering machine.

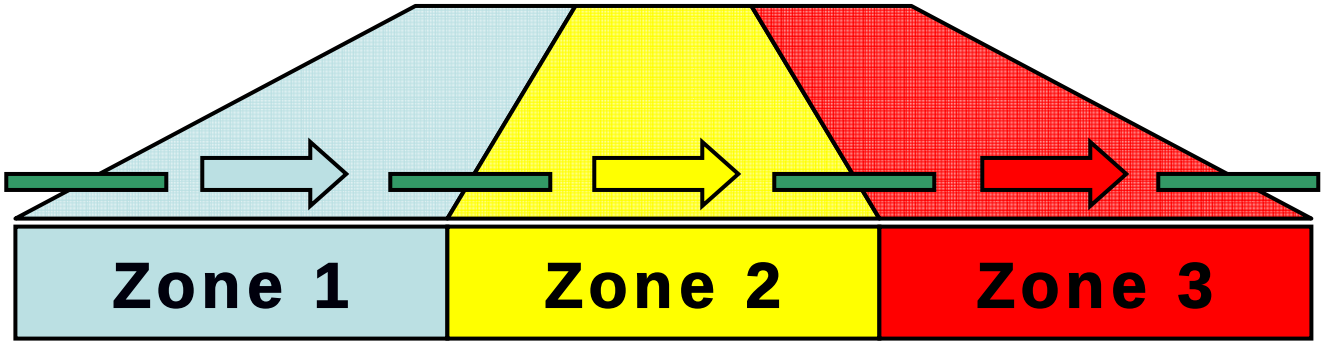
- **Increase preheater capacity**
- **Switch to external heaters**
- **Modify general design and layout of the wave soldering machine**

Typical thermal profile for SN100C



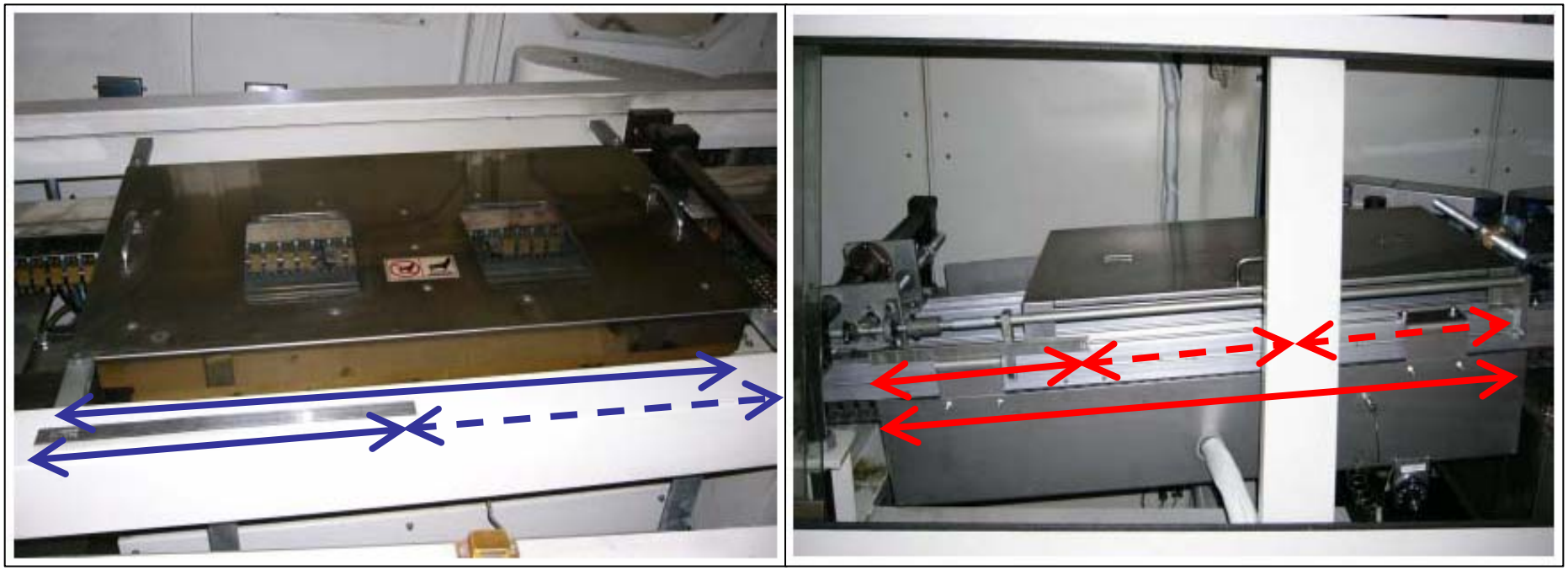
Preheater capacity

Multi zone-preheater is more efficient and preferable for lead-free soldering.



Preheater capacity

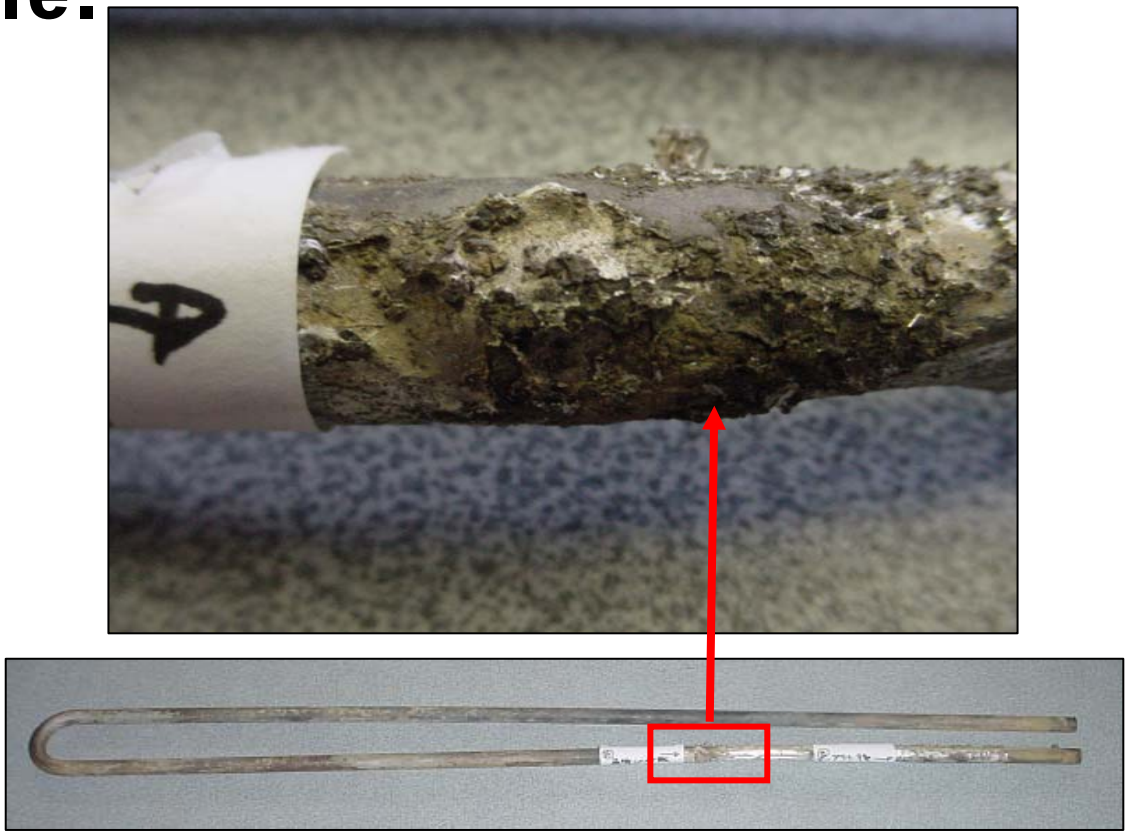
Longer preheater is more efficient and preferable for lead-free soldering.



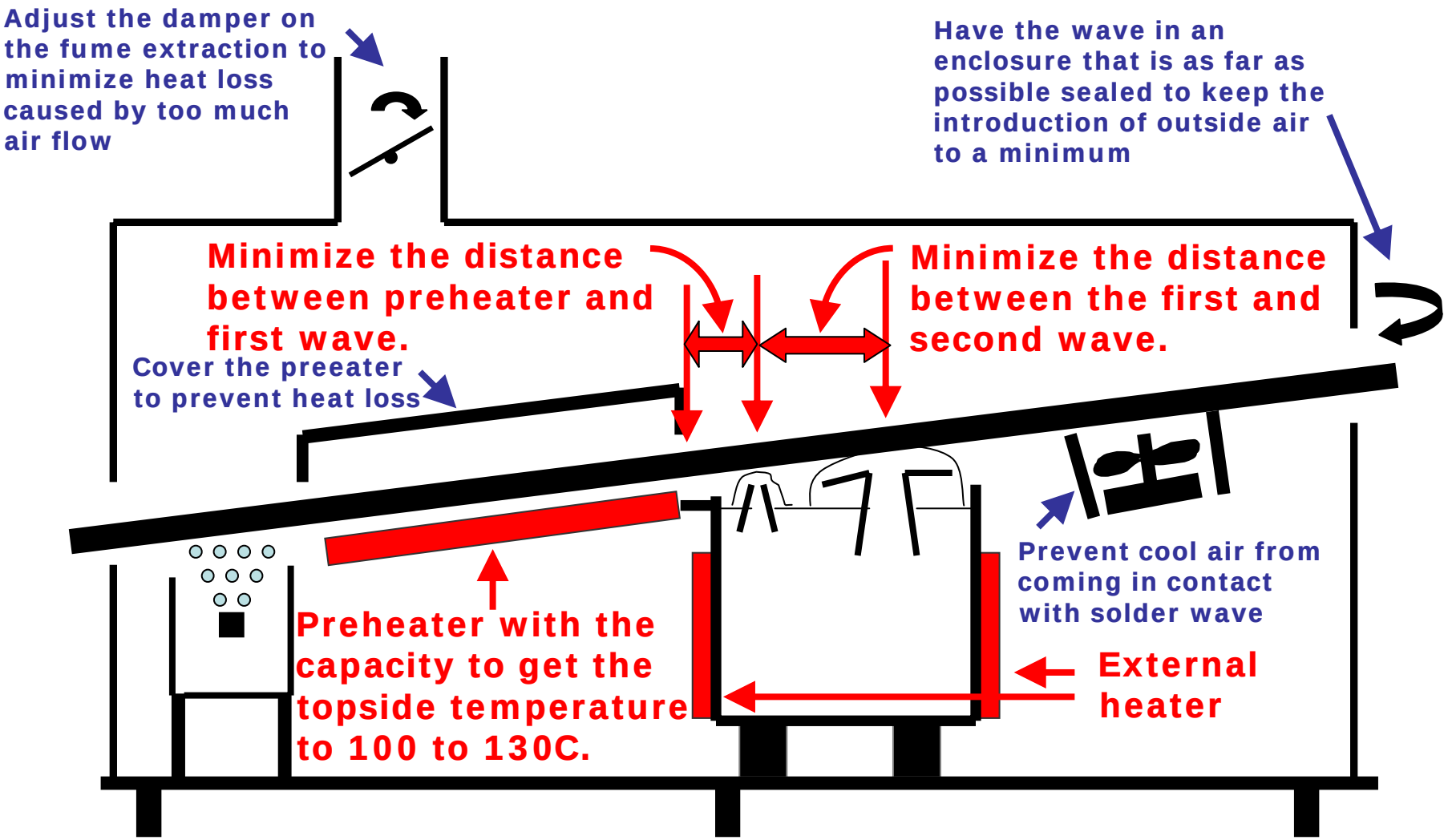
***Length of solder bar: approx 330mm**

External heater

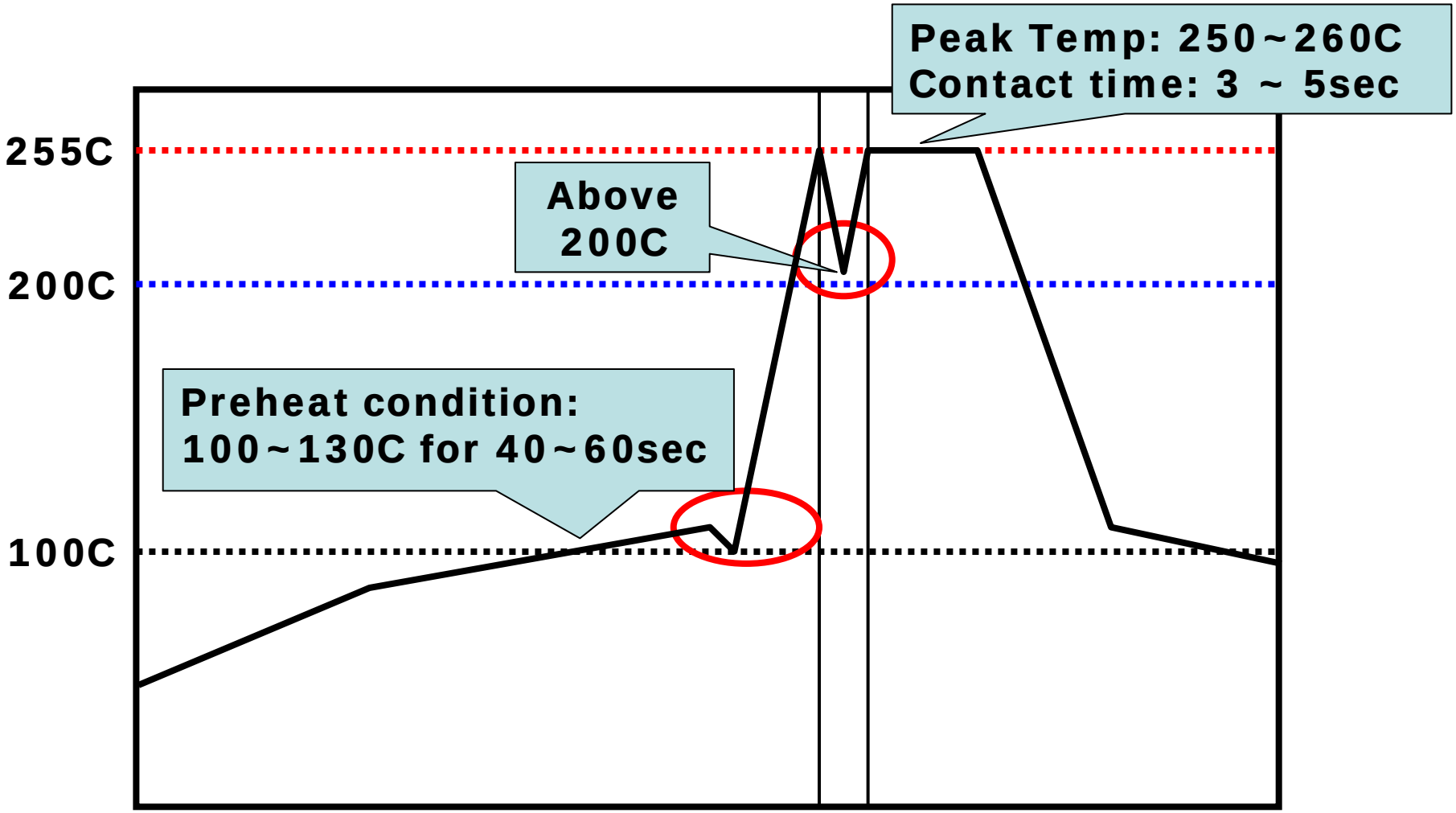
Internal heater will be eroded by lead-free solder, so that external heater would be preferable.



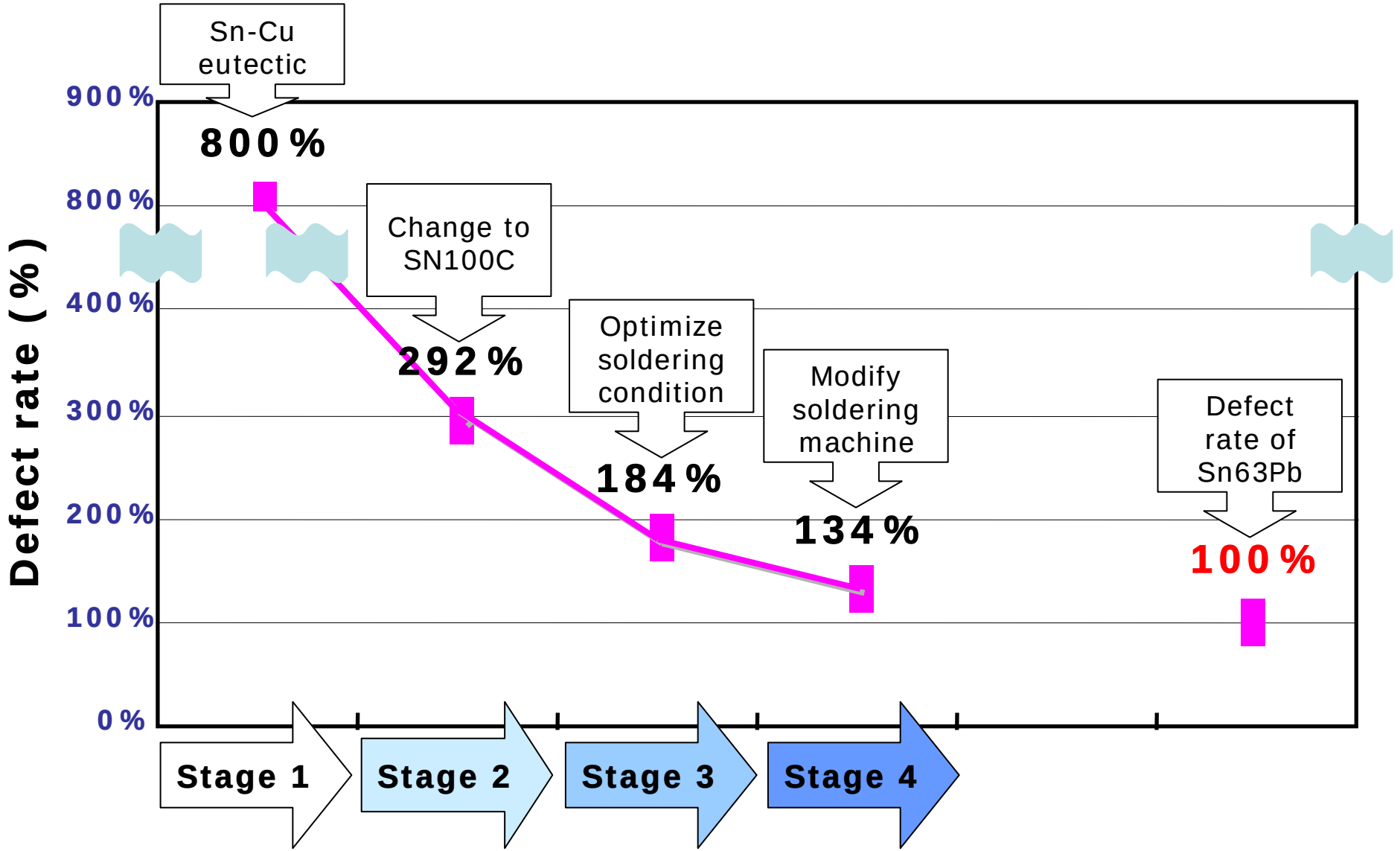
Modify general design and operation



Typical thermal profile for SN100C



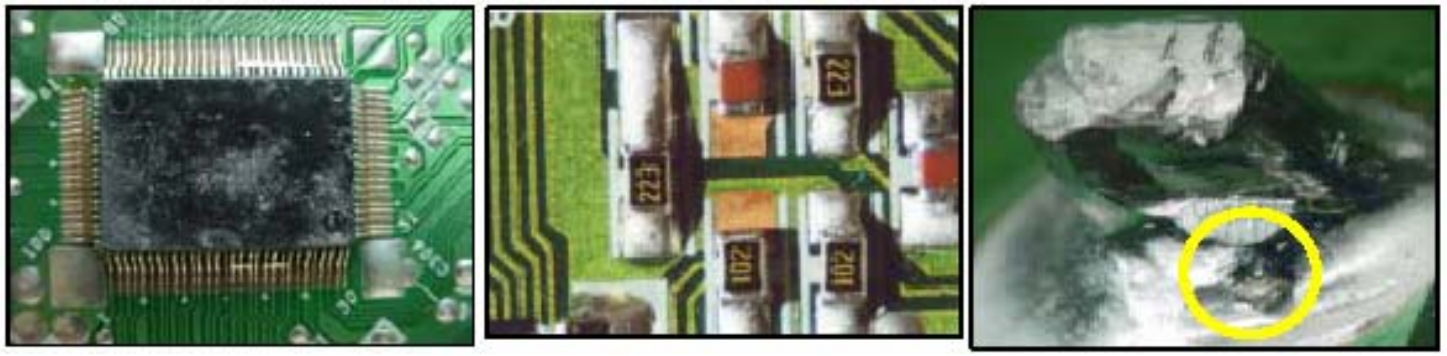
A lead-free wave soldering learning curve



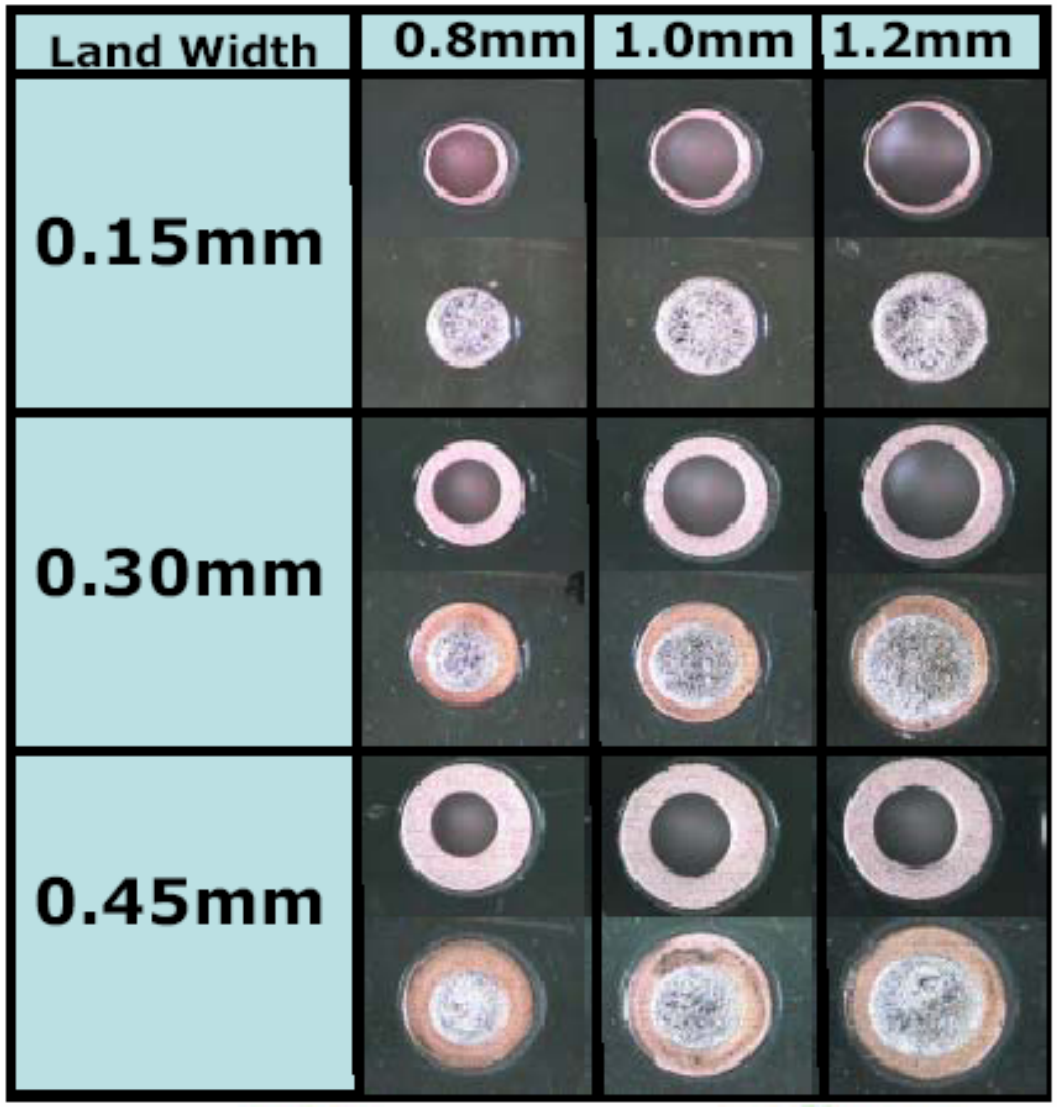
Lesson5: Modification of design

Even after Stage 4, defect rate was still 30%. There was still room for further improvement by

- **Modification of lands**
- **Modification of board layout**
- **Modification of component design**

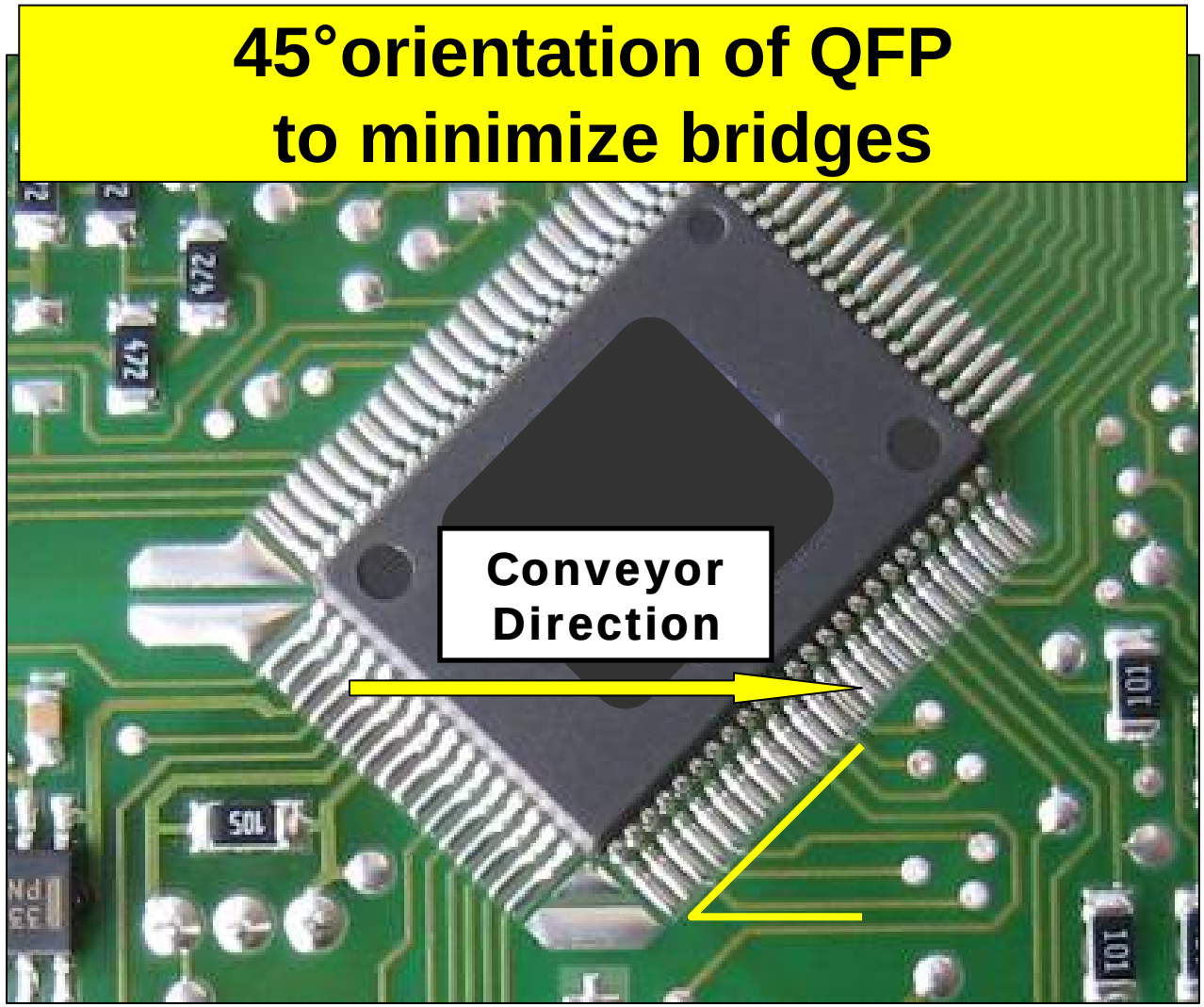


Width of land

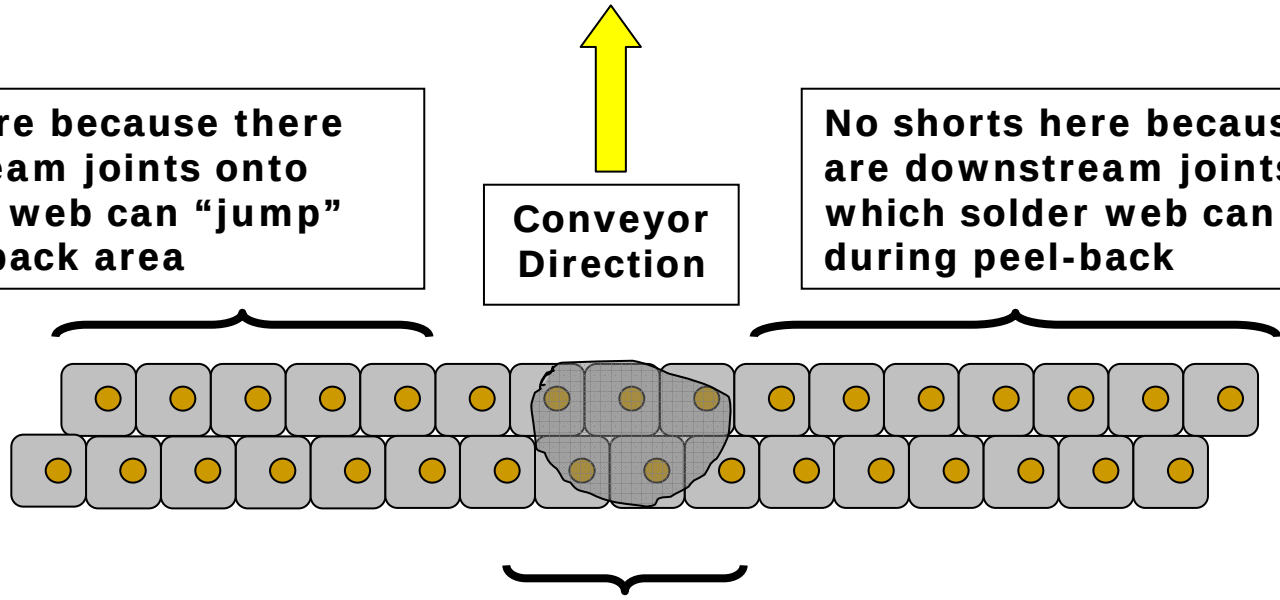


[Test Conditions]
Solder: SN100C
Flux: NS-828B Rosin Type
Temperature: 255C
Contact Time: 3.5sec

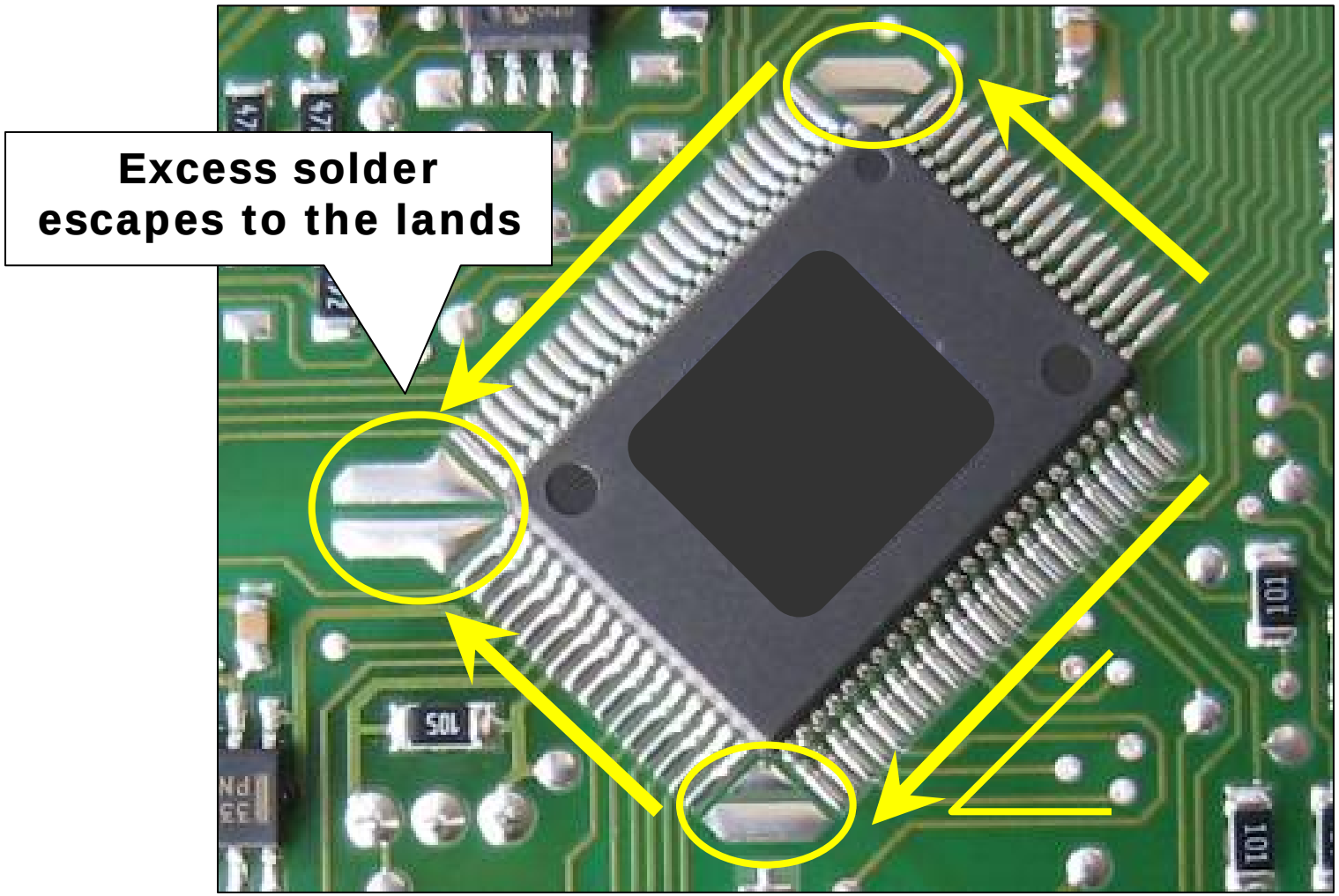
45°orientation of QFP



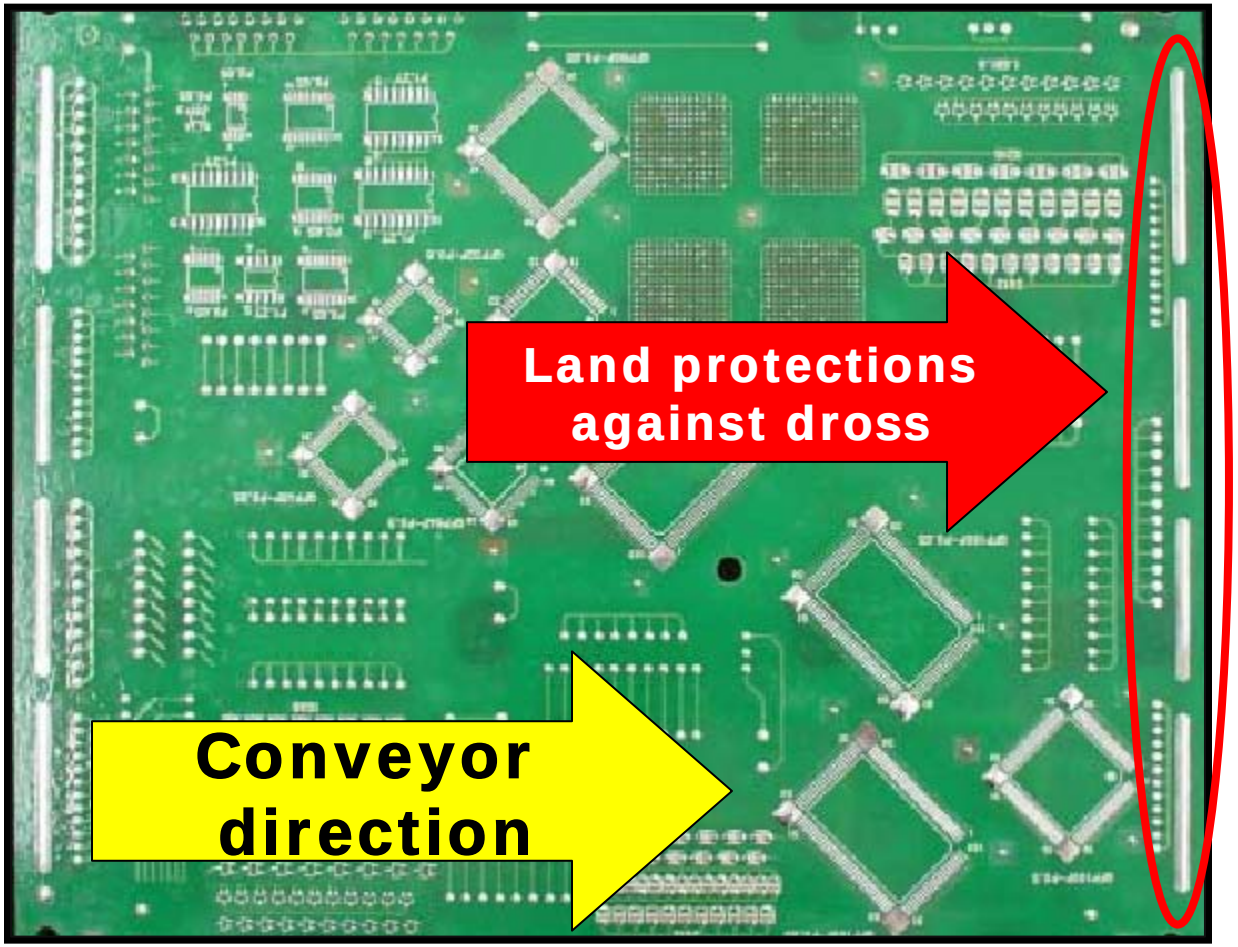
Minimizing bridges



Solder thieves

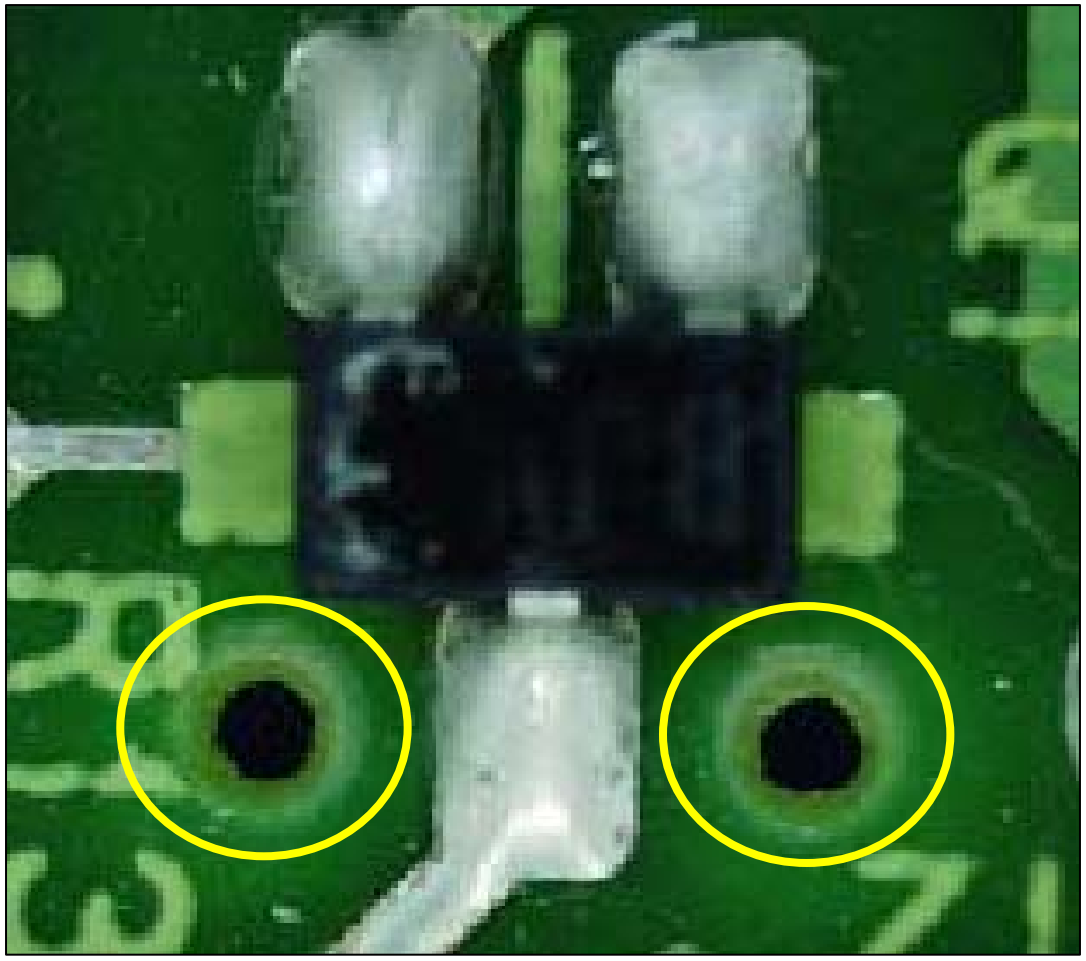


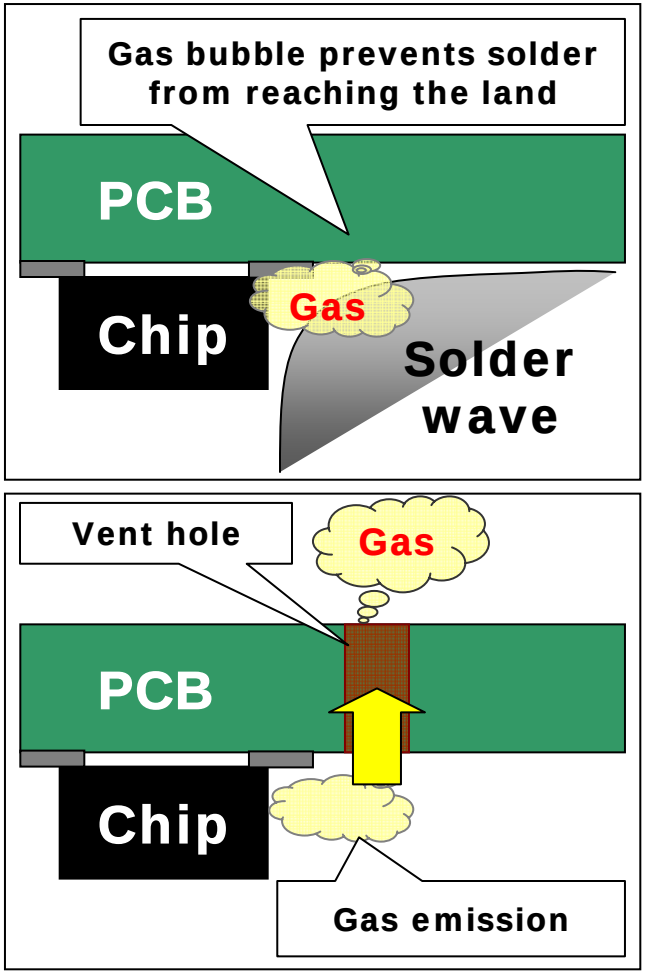
Minimizing bridges



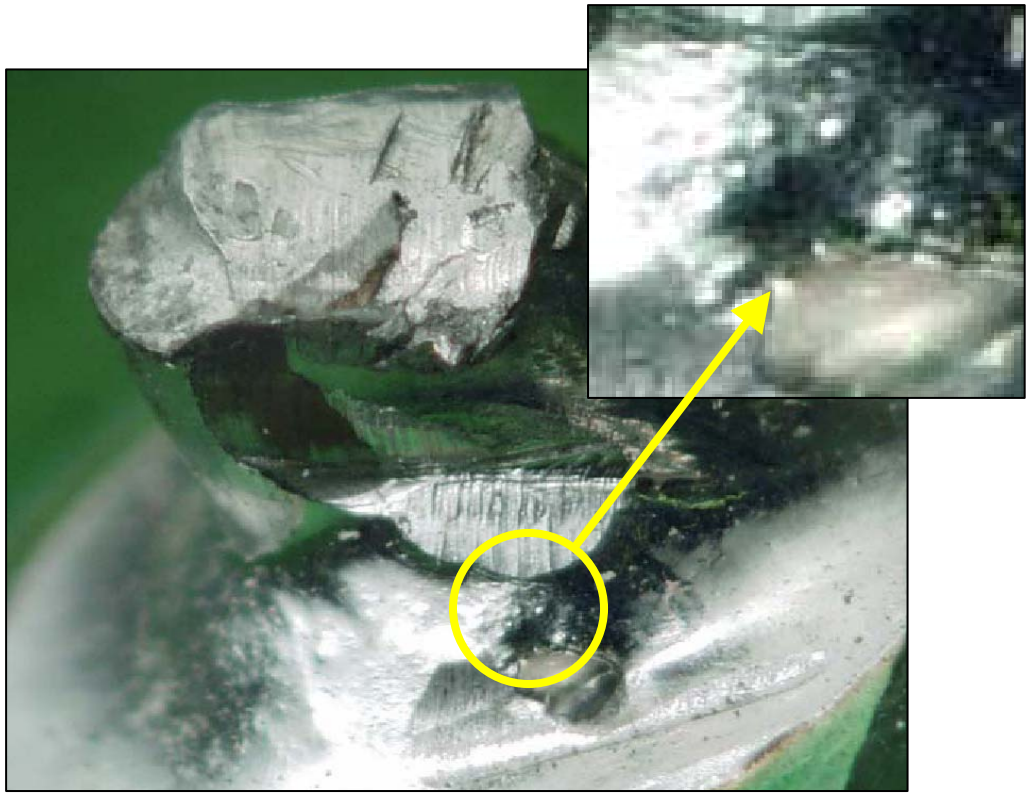
Dummy lands in the front line of a board, they protect component terminations from oxides.

Vent holes

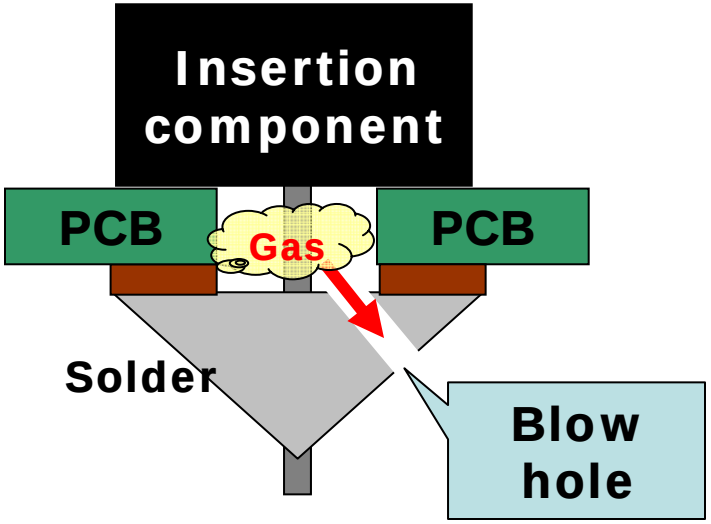



Gas bubble prevents solder from reaching the land
PCB
Chip
Gas
Solder wave
Vent hole
Gas
PCB
Chip
Gas emission

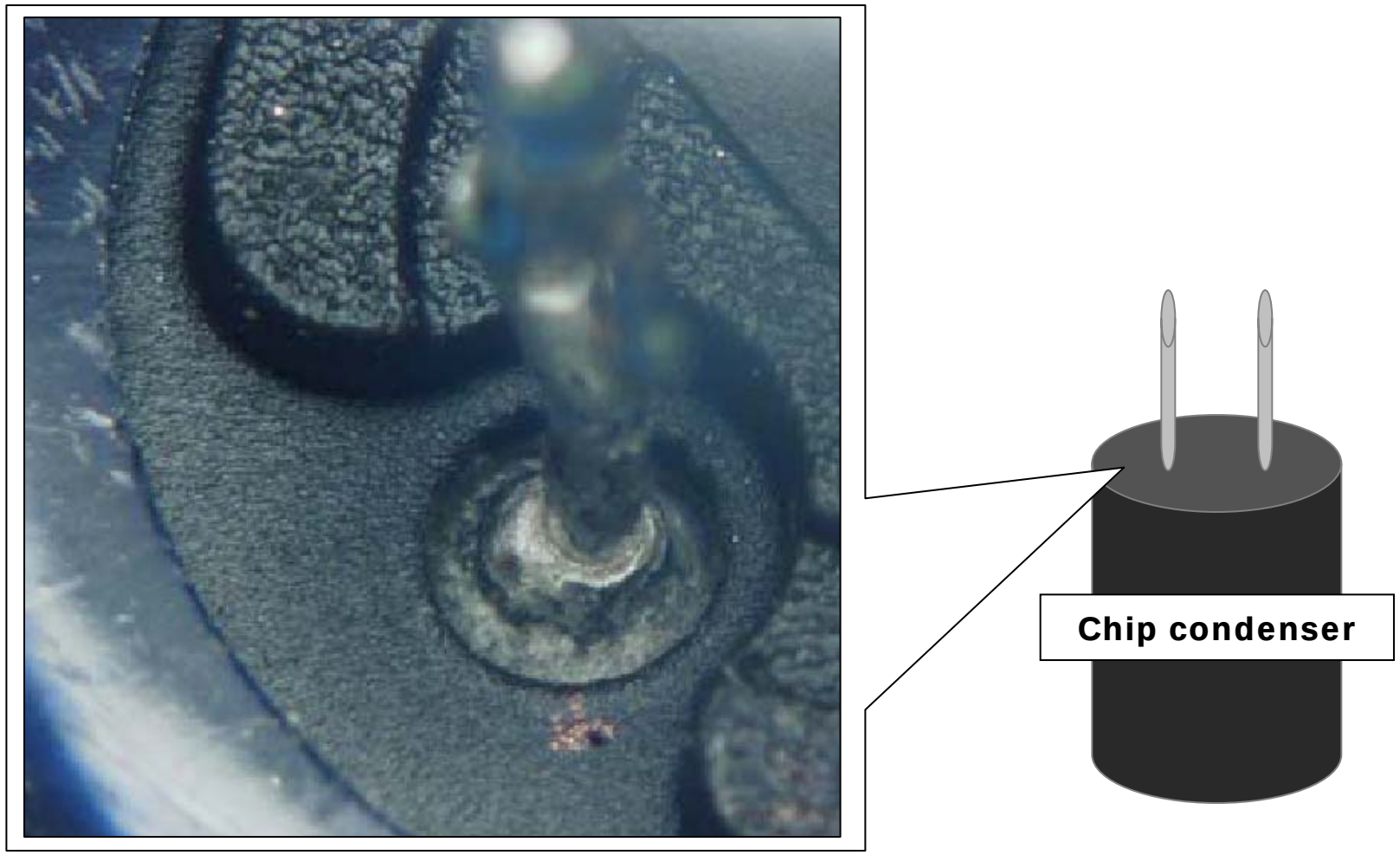
Modification of component design



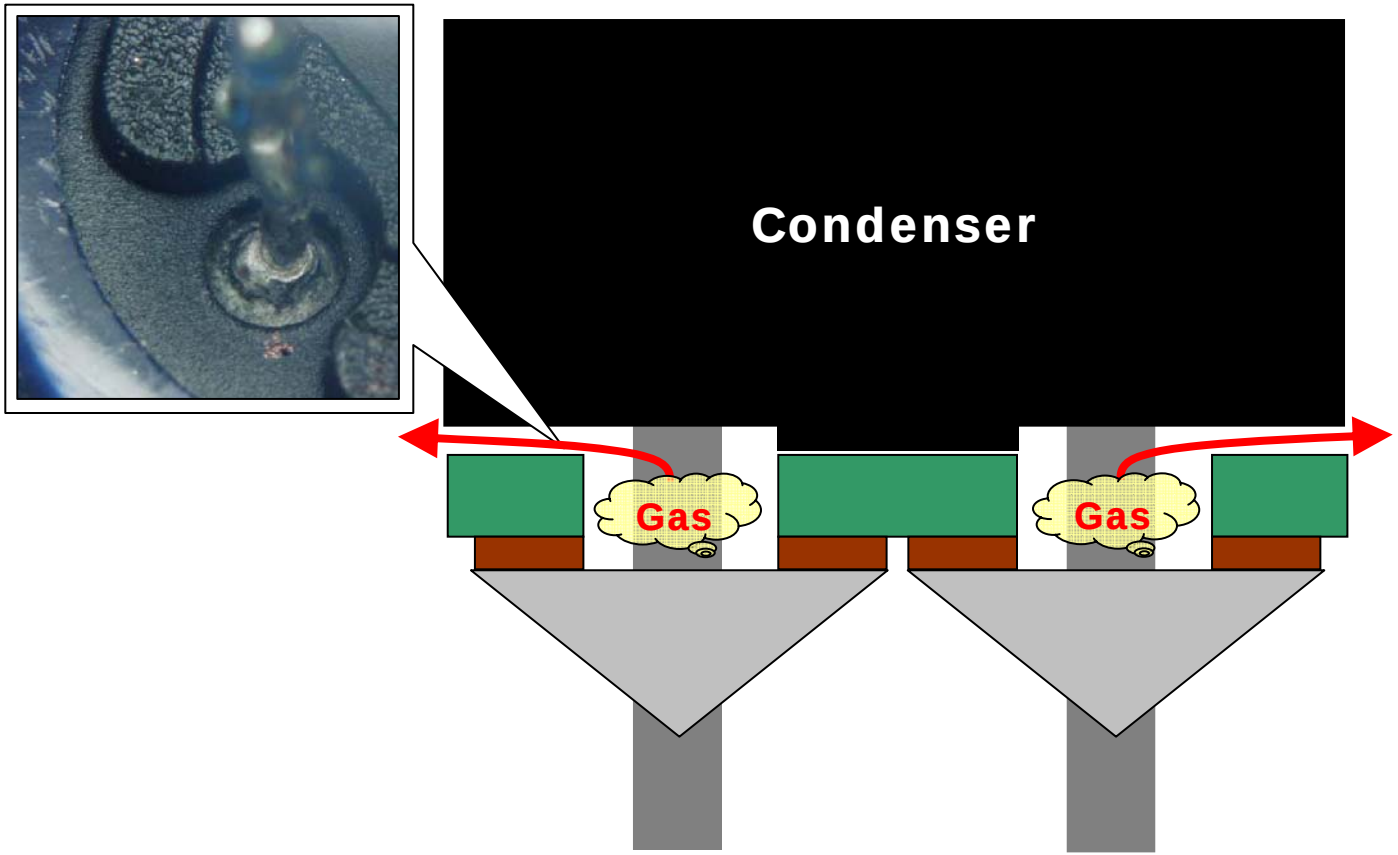
Solder expulsion trapped gas



Modification of component design

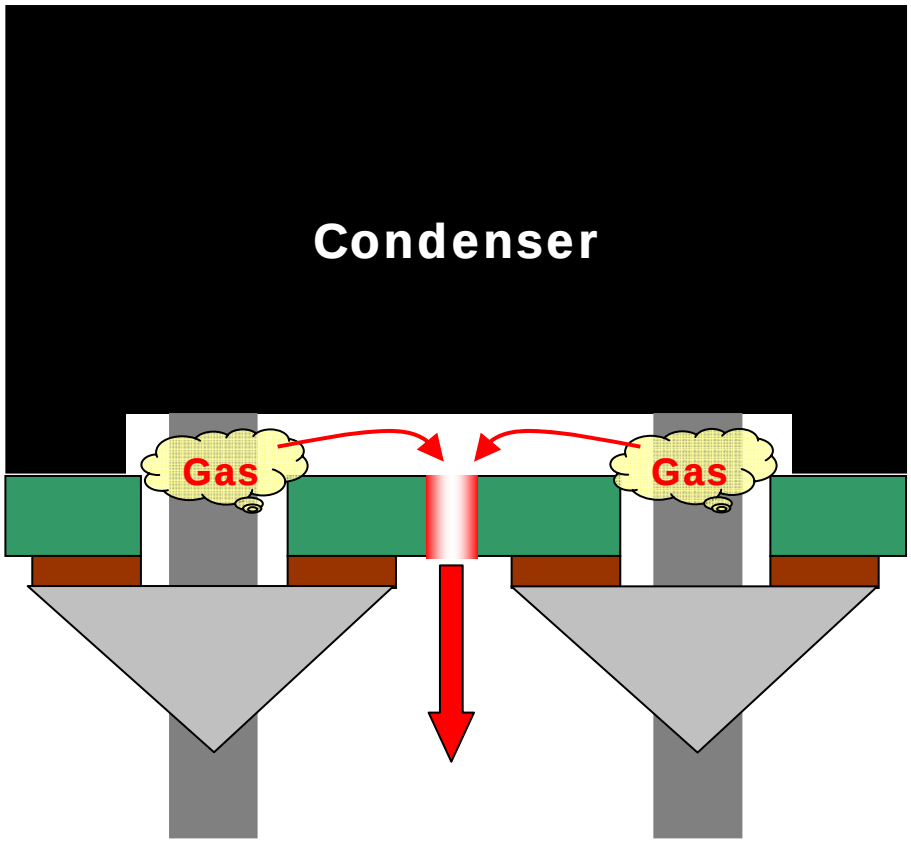


Gas out



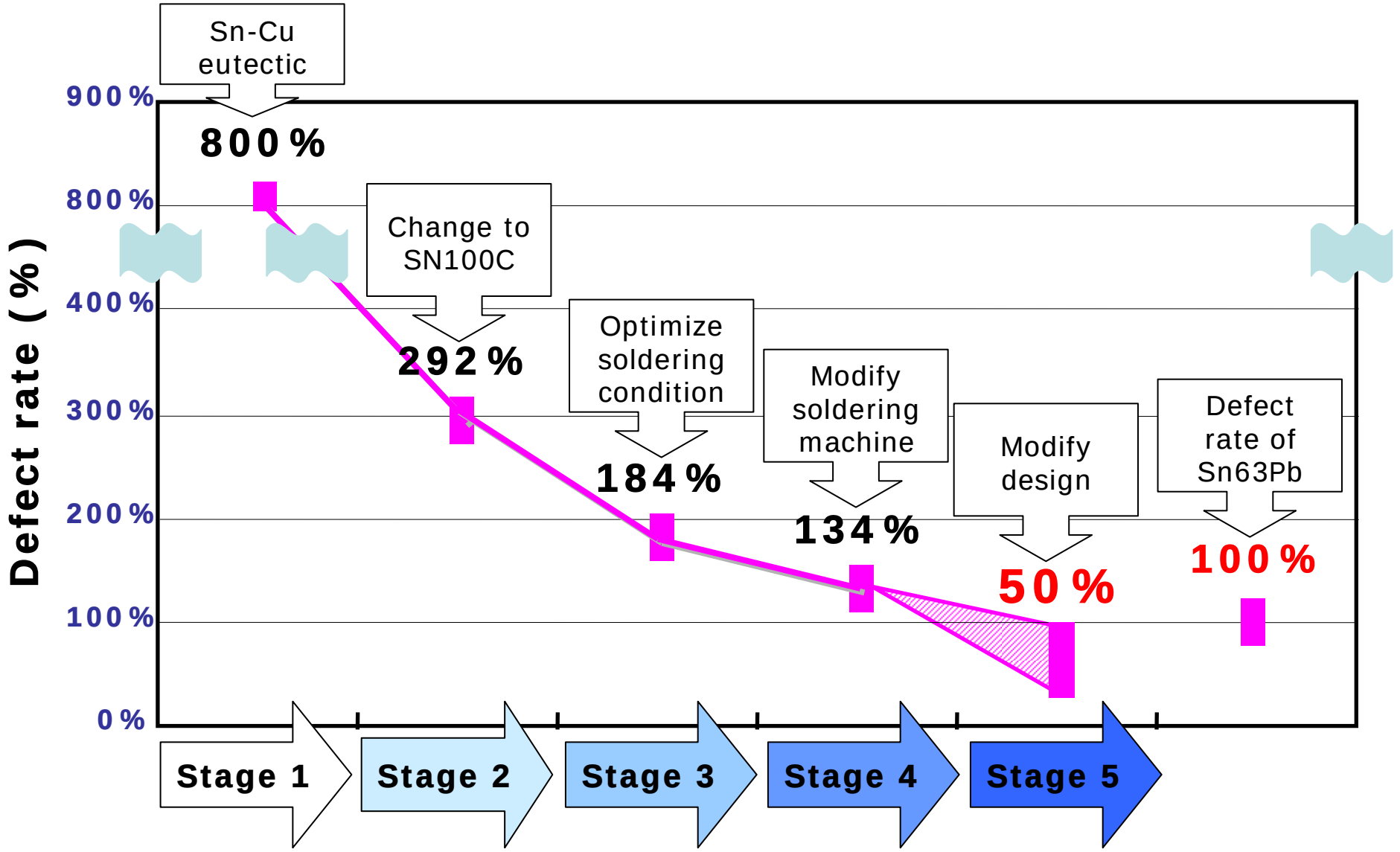
Because of the bump, trapped gas can be out.
As a result, problems due to gas can be minimized.

Gas out



**If a component does not have the bump,
a vent hole could be made on boards instead.**

A lead-free wave soldering learning curve



Summary

In summary, the stages from the beginning of the optimization of the wave soldering process were as follows. (Defect rate 50%)

Stage 1: Choose the Sn-Cu eutectic as the best alloy for lead-free wave soldering

Stage 2: Switch to a patented alloy with controlled additions of Ni and Ge to overcome the deficiencies of the basic of Sn-0.7Cu alloy.

Stage 3: Optimize the process parameters

Stage 4: Modify the wave soldering machine

Stage 5: Modify the design

Conclusion

The keys to a successful conversion to lead-free soldering are…

- **Control of heat**
- **Adjustment of process parameters**

Not all the problems encountered in the conversion to lead-free solder can be solved by selection of the right solder alone.

It is important to understand the properties of solder and how to adjust process parameters to reflect properties.

Thank you very much!!

NIHON SUPERIOR NSe LEAD FREE e-SOLDER