Next generation LMPA for heat sensitive substrates and components

Summary Low Melting Point Alloys

- History behind LMPA
- Differences between LMPA’s
- LMPA properties
- Application areas
- Application limitation and Additional benefits.

AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

OPTIMIZING SOLDER ALLOY COMPOSITION FOR LOW TEMPERATURE ASSEMBLY

Why low temperature assembly?

- **Reduce energy consumption** → Reduced emission of toxic pollutants and greenhouse gases
- **Make possible the use of temperature sensitive packaging materials and substrates** → Additive manufacturing, wearable electronics, medical devices
- **Make possible the use of cheaper packaging materials and substrates** → Service temperatures much lower than process temperatures

AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

Reducing Peak Reflow Temperature

- Superheat necessary to get the joints to wetting temperature

Two factors contributing to process temperature:

- Melting temperature of solder alloy

Example:

- SAC305 melts over a range 217-220˚C
- Typical peak reflow zone temperature 235-245˚ C
- “Superheat” 15-25˚C

Depending on thermal mass of board and components

AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

Low Temperature Solder Alloy Formulation

The starting point is tin (Sn)

Forms IMC with and wets most substrates. Low melting point. Non-toxic

Adding other elements usually reduces the melting point

- Sn-Cu eutectic 227˚C
- Sn-Ag eutectic 221˚C
- Sn-Ag-Cu eutectic 217˚C
- Sn-Bi eutectic 139˚C
- Sn-In eutectic 120˚C
- Sn-Ga eutectic 15˚C

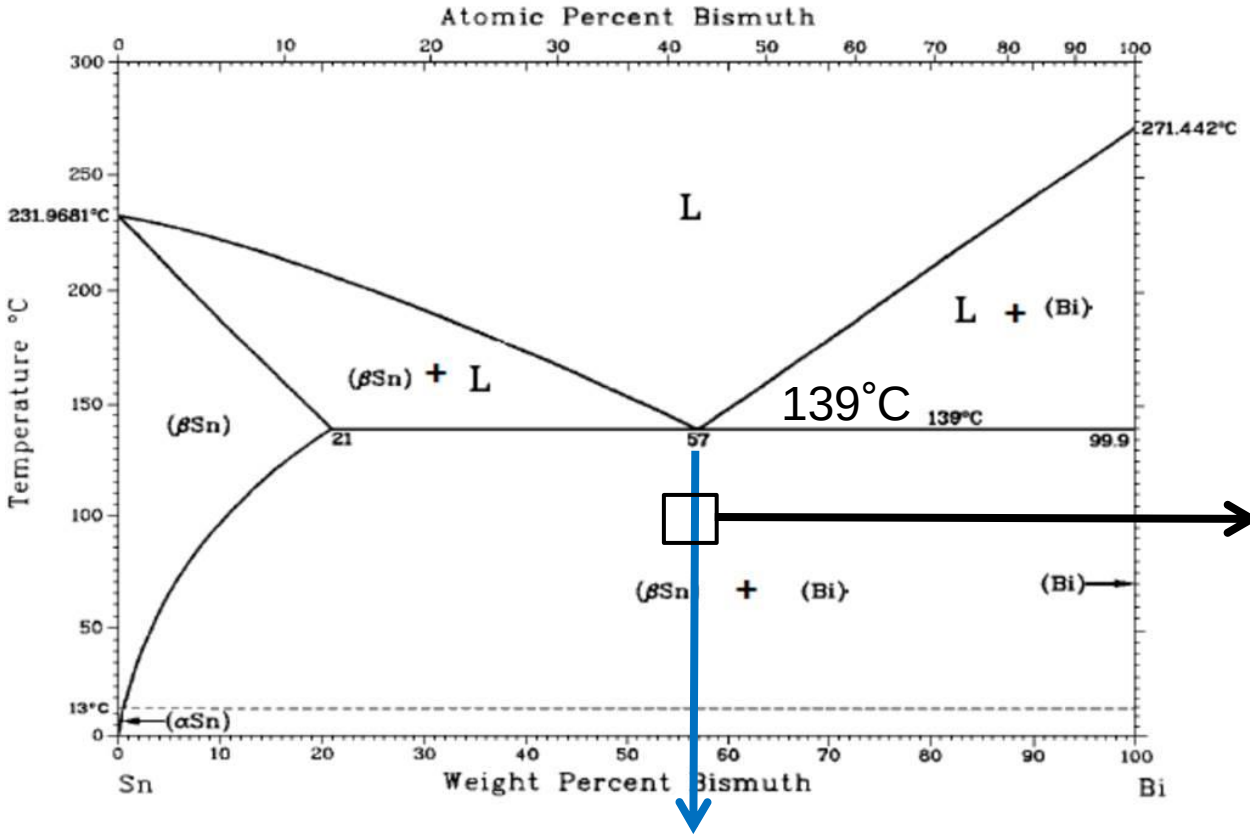
Right melting point range
Reasonable raw material cost

If the composition is a eutectic the alloy should have a sharp melting point like a pure metal

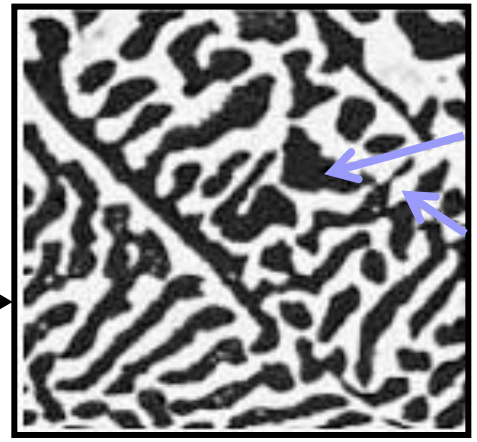
If the mix is off-eutectic the alloy will have a melting range, extending from the solidus to the liquidus

AQC
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

Starting with the Sn-Bi eutectic…



Eutectic Microstructure

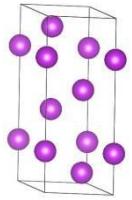


Tin

Bismuth

57% Bi

The matrix is the bismuth phase



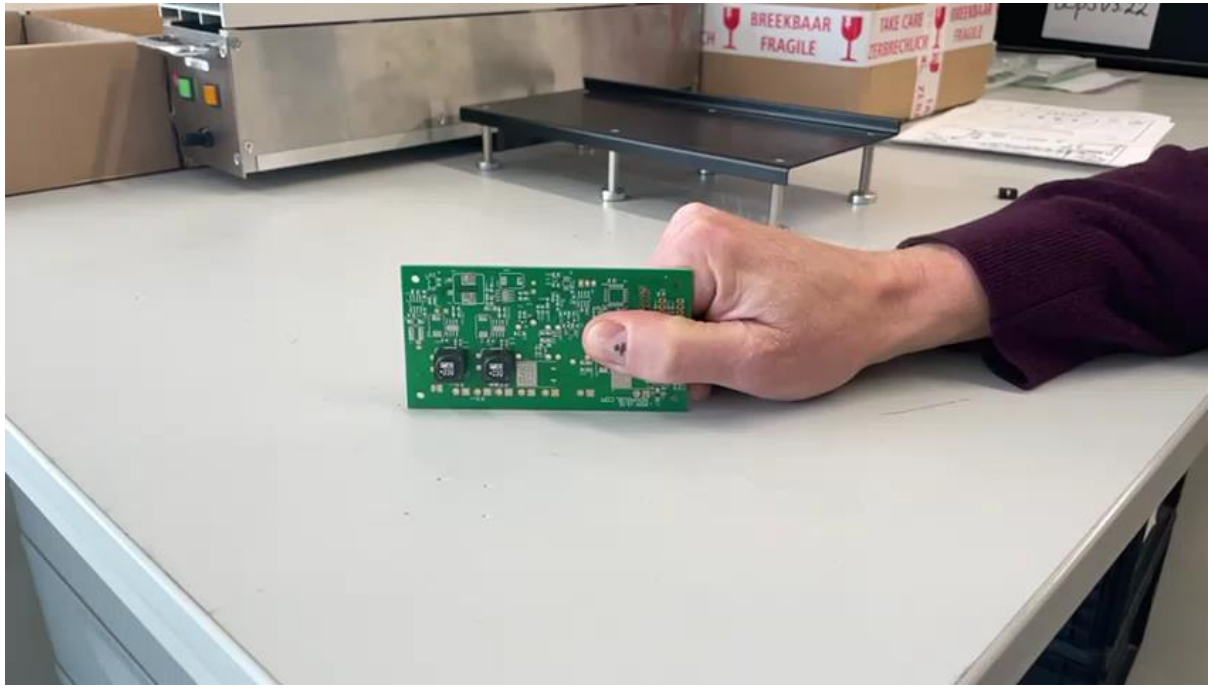
Rhombohedral crystal lattice

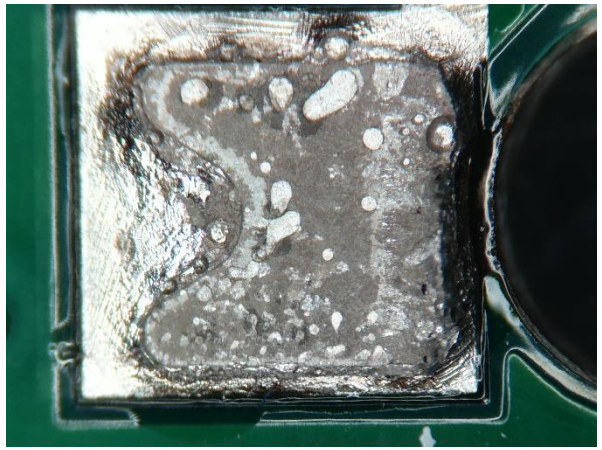
Tendency to brittle failure

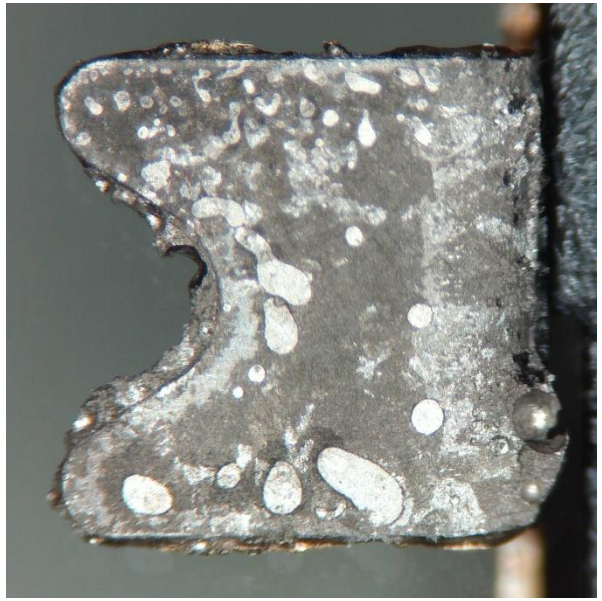
AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

Brittleness eutectic SnBi



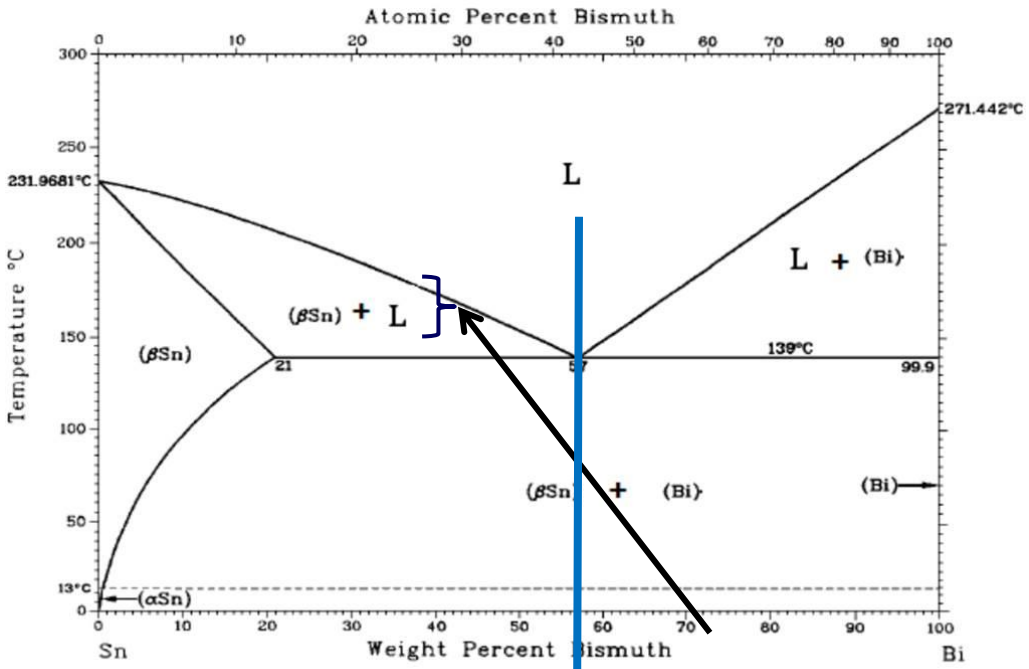




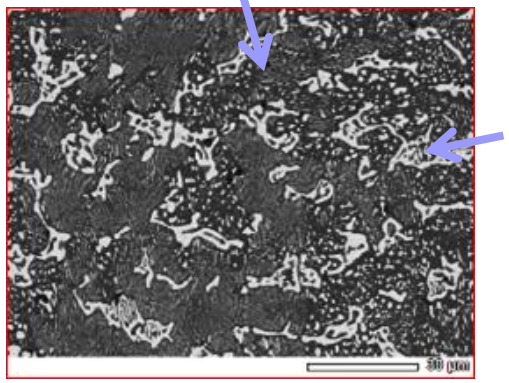
AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

Moving to a lower Bi level…



Microstructure dominated by primary tin dendrites



Tin-bismuth eutectic in interdendritic spaces

~38% Bi

- Loses sharp melting point of eutectic
- Freezes over a range from **~175-139℃**

AQC
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

Strengthening mechanisms…
Alloying addition options for Tin-Bismuth

Antimony (Sb)

- Soluble in tin and bismuth providing solid solution strengthening
- At higher concentrations may form intermetallic compound SbSn that could provide particle strengthening

Silver (Ag)

- No solubility in tin or bismuth.
- Forms intermetallic compound Ag_3Sn that can provide particle strengthening

Copper (Cu)

- No solubility in tin or bismuth
- Forms intermetallic compound Cu_6Sn_5

Nickel (Ni)

- No solubility in tin or bismuth
- Can form intermetallic compounds with tin, which could provide particle strengthening
- Incorporates into the crystal structure of Cu_6Sn_5 stabilizing to ambient temperatures the hexagonal form that would otherwise undergo polymorphic transformation to the monoclinic form at temperatures below 186℃

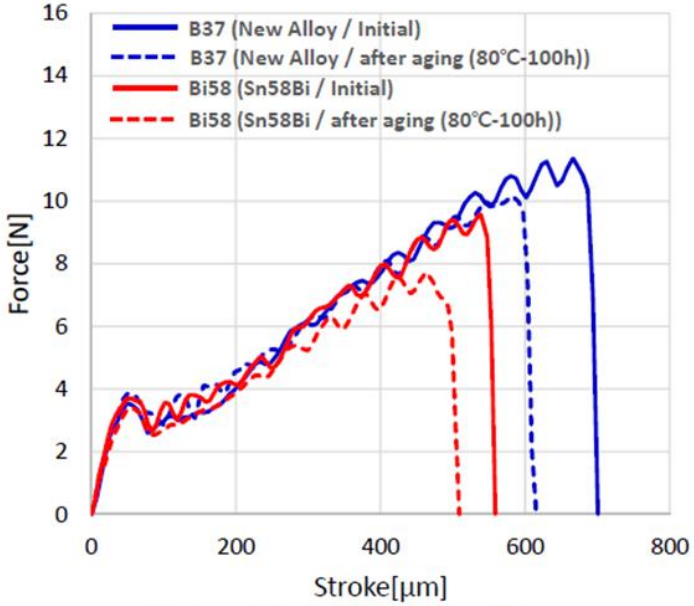
Germanium (Ge)

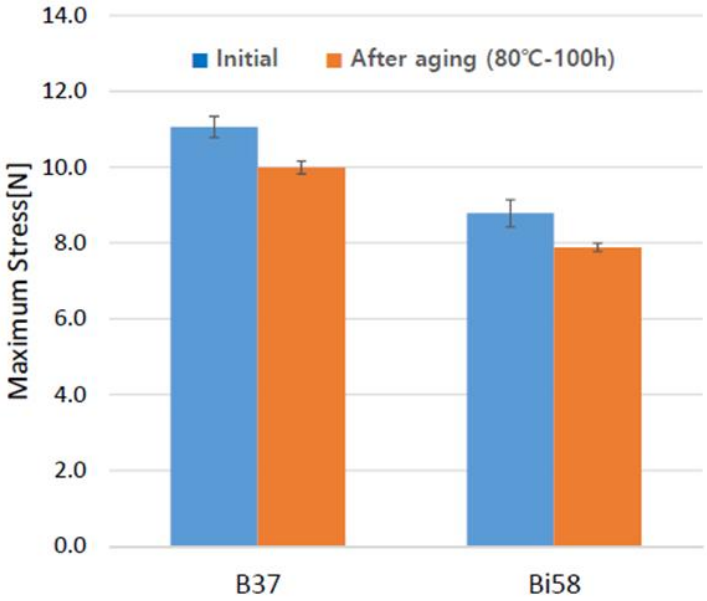
- No solubility in tin or bismuth
- Potential particle strengthener
- Antioxidant (dross suppressor)

AQC
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

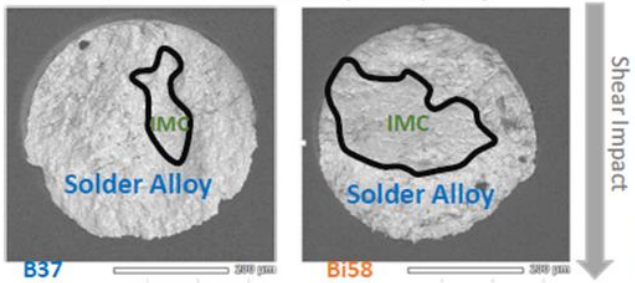
Shear test eutectic SnBi vs next gen LMPA

Ball Shear Testing Result





Surface of fracture point (SEM)



BGA	500μm
Board	FR-4 (Cu-OSP)
Shear Speed	10mm/sec

Solder alloy area in fracture point of B37 New Alloy is wider than the area of Bi58. It means that B37 has better stress absorption. B37 is keeping it in higher level after aging in 80℃-100h.

Composition next generation LMPA

Sn-37Bi-0.5Sb-0.5Cu-0.05Ni
Sn-40.5Bi-0.5Sb
Etc.

AQC

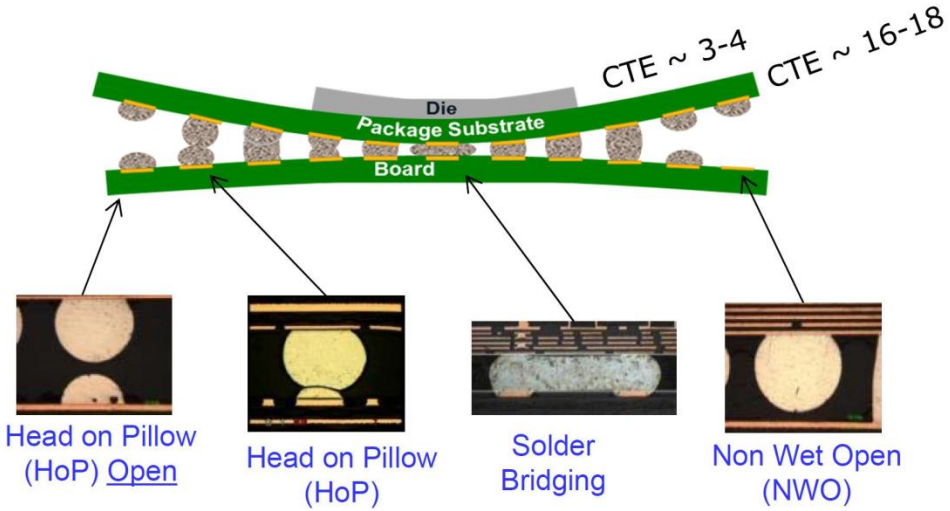
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

OPTIMIZING SOLDER ALLOY COMPOSITION FOR LOW TEMPERATURE ASSEMBLY

Why low temperature assembly?

- **Reduced incidence of defects caused by package warpage**

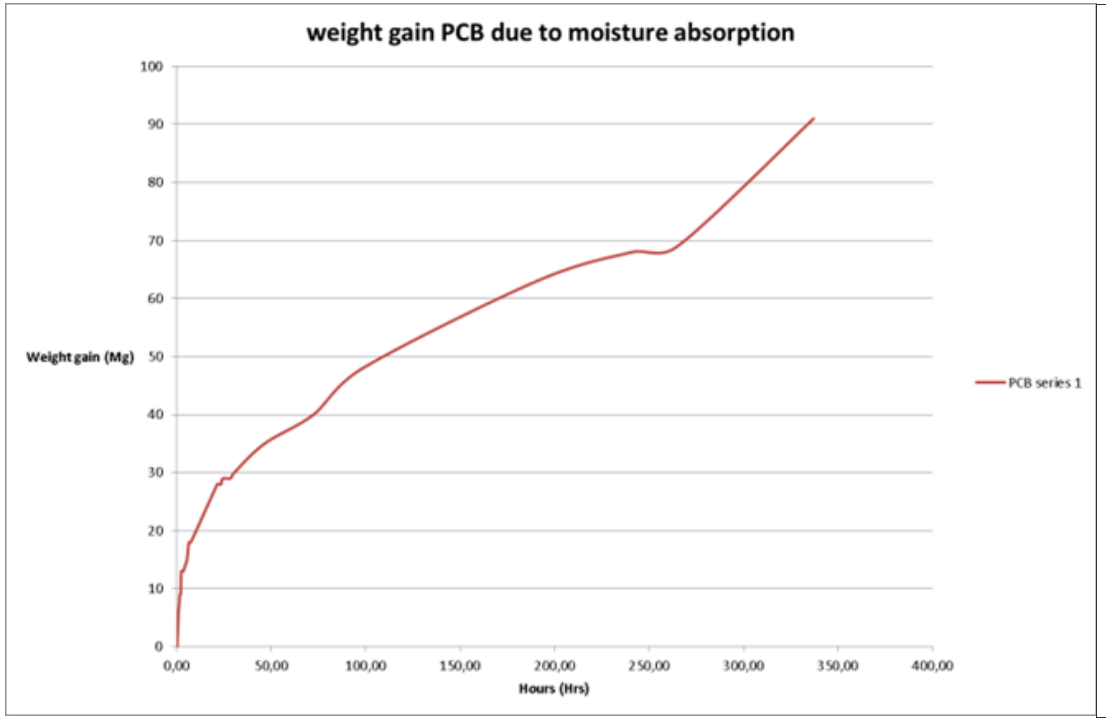
Peak Reflow Temperature ≤ 200C

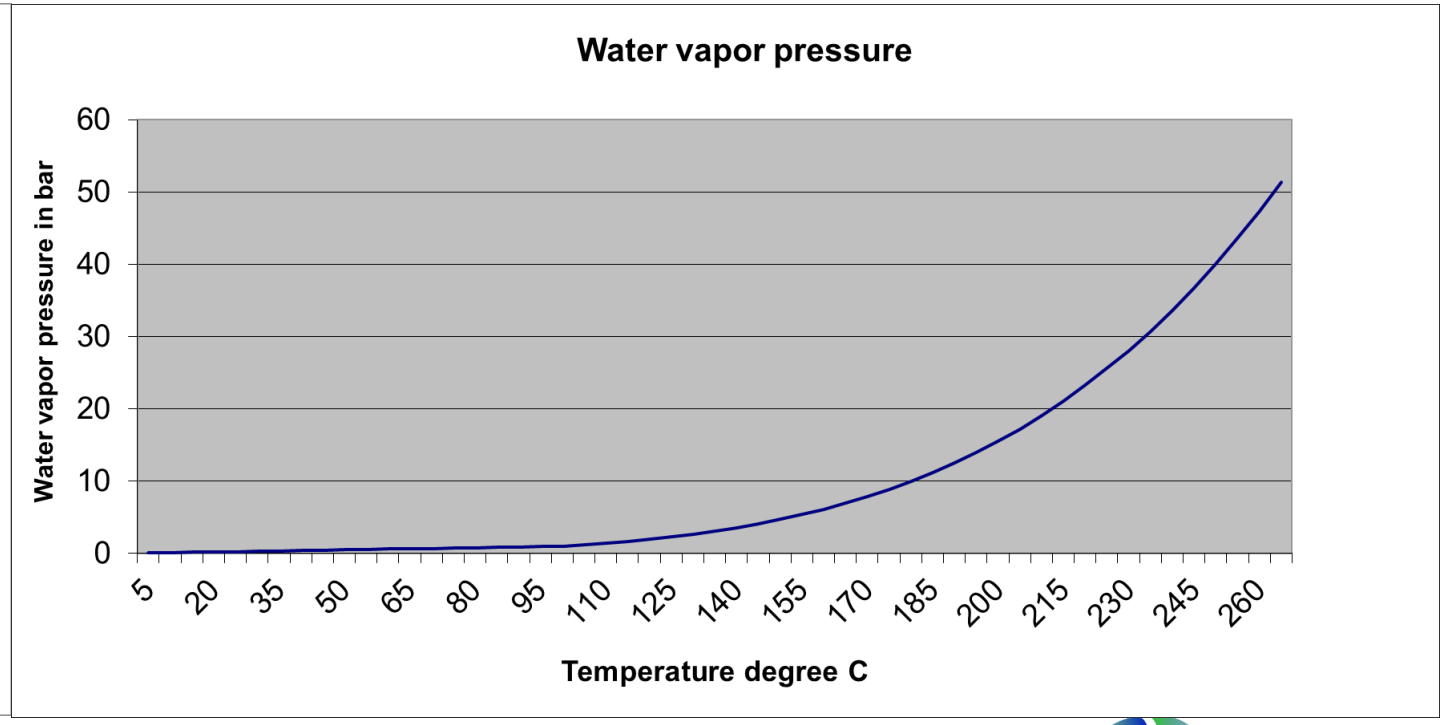


Scott Mokler et al. "The Application of Bi-Based Solders for Low Temperature Reflow to Reduce Cost While Improving SMT Yields in Client Computing Systems." *Proceedings of the SMTA International Conference, Rosemont, IL, Sept 2016.* .

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

Hygroscopic behaviour Polyimide



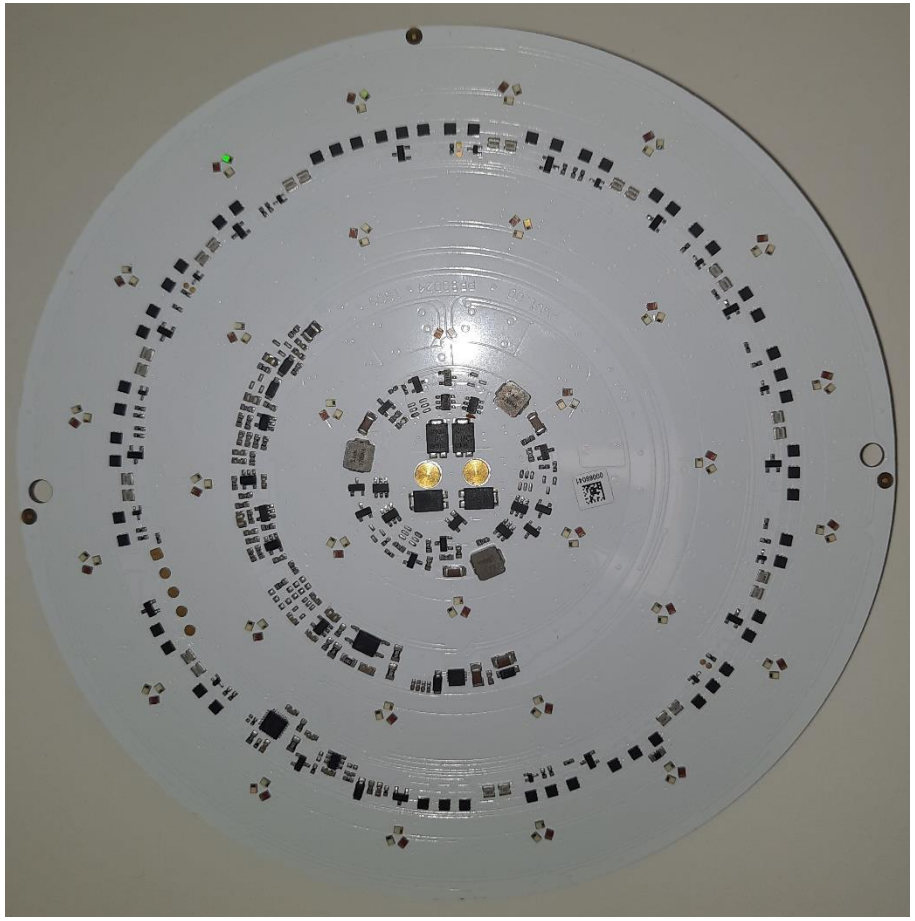


Polyimide material is most commonly used to produce flexible and flex-rigid boards because the material is exceptionally flexible, chemical resistant, thermally stable up to 260C, etc.

Moisture inside polyimide can cause delamination during the assembly process. Reducing the assembly process temperatures will prevent delamination

AQC
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

No or very low discolloration of white soldermask after the reflow process



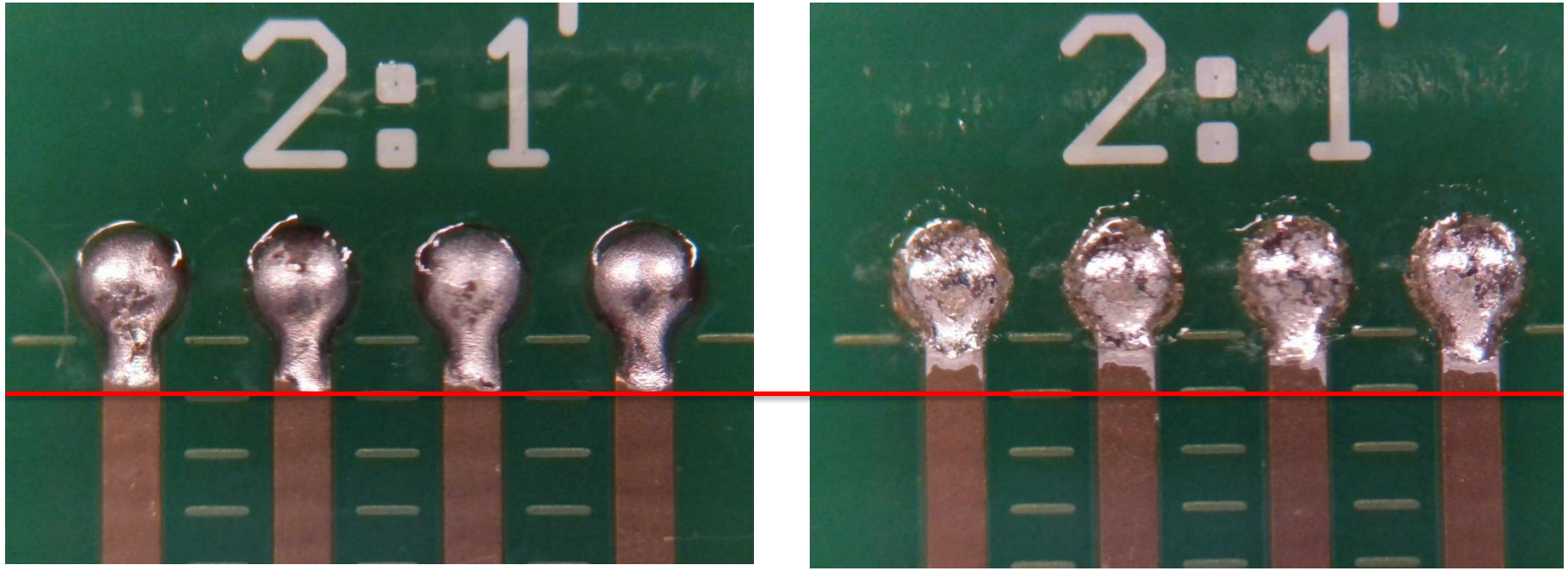
Traditional white soldermask commonly used for LED applications. This low cost soldermask has the intention to show yellowness after reflow.

AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

All next gen LMPA show Excellent wetting

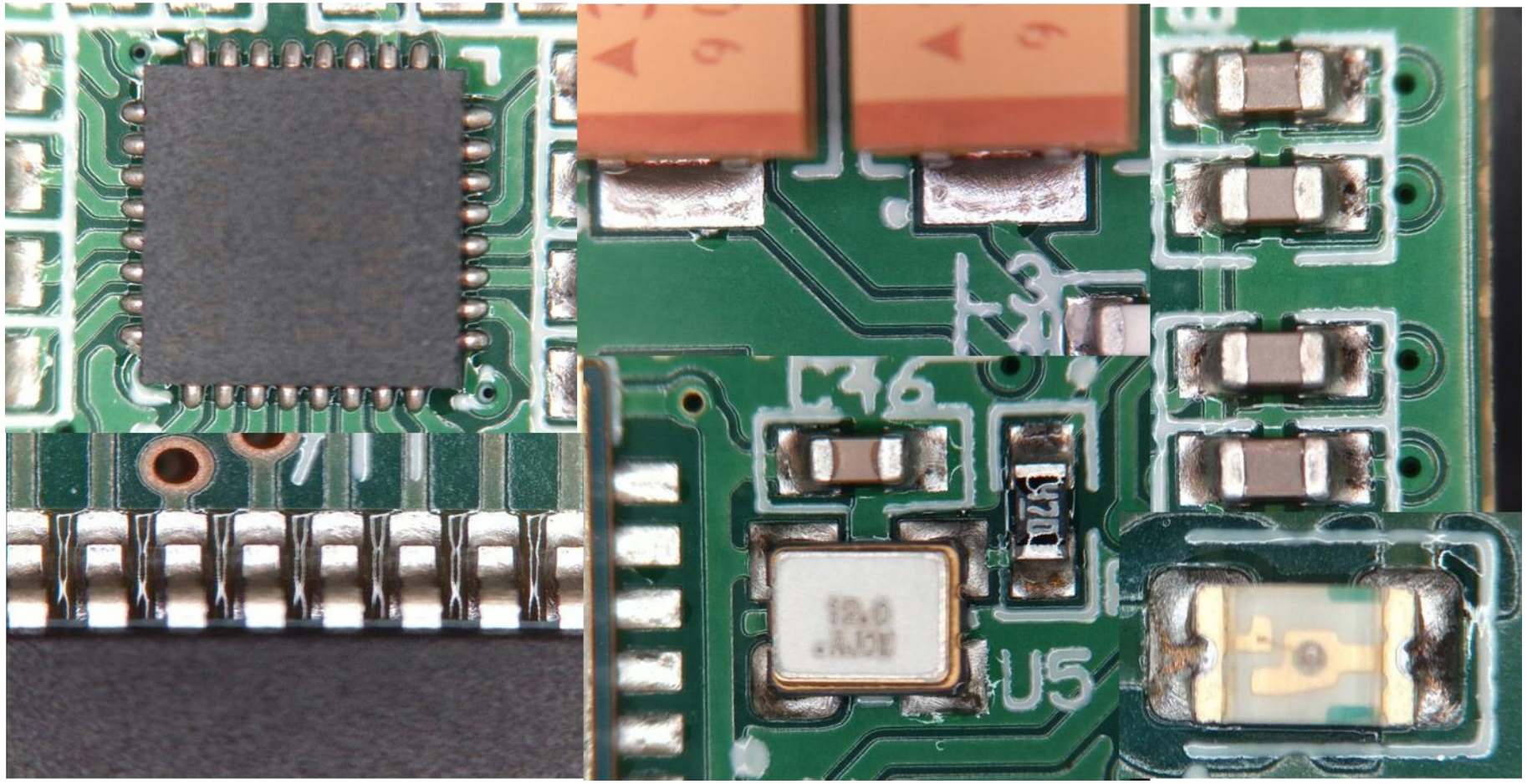
LMPA **Lollipop** SAC305



AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

All next gen LMPA show excellent wetting

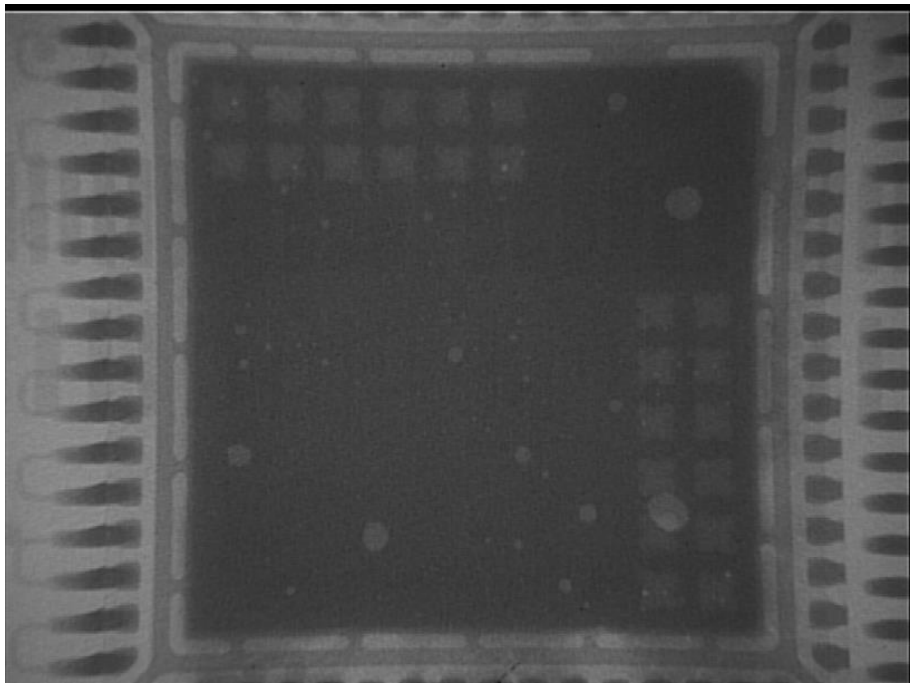


AQC

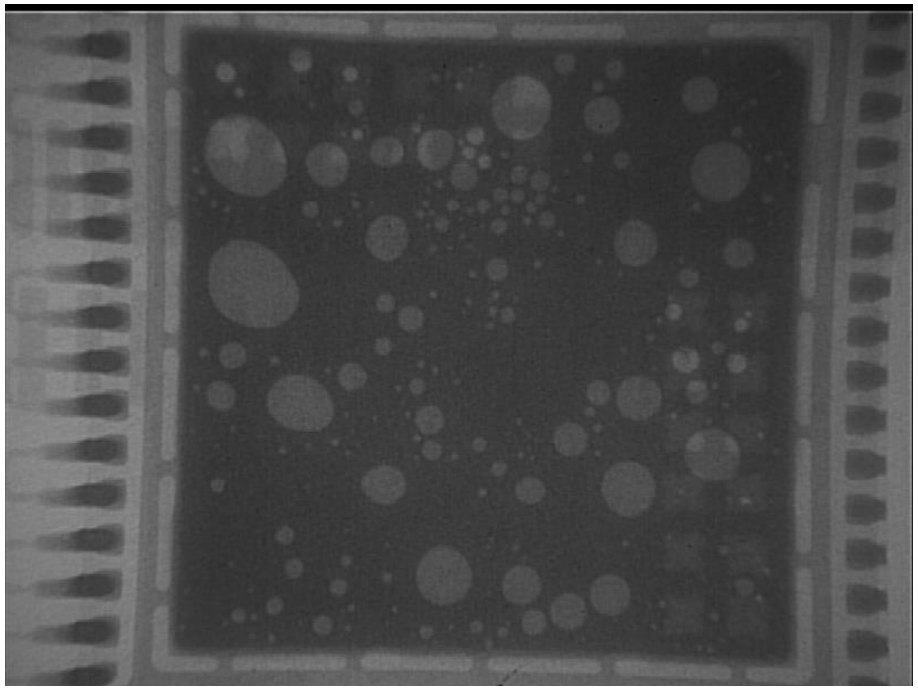
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

All next gen LMPA show Low voiding

LMPA



SAC305



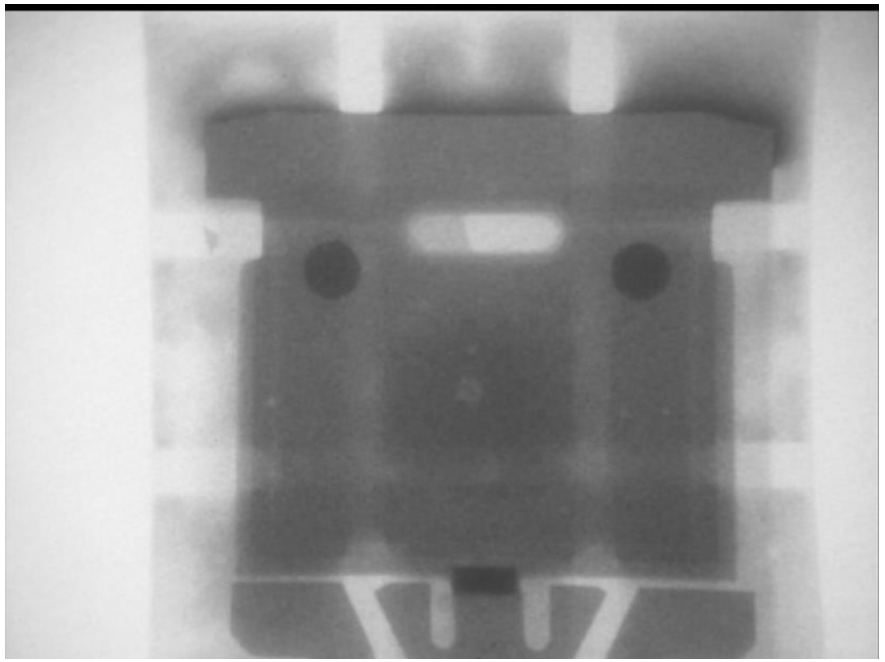
QFN64 9X9mm

AQC

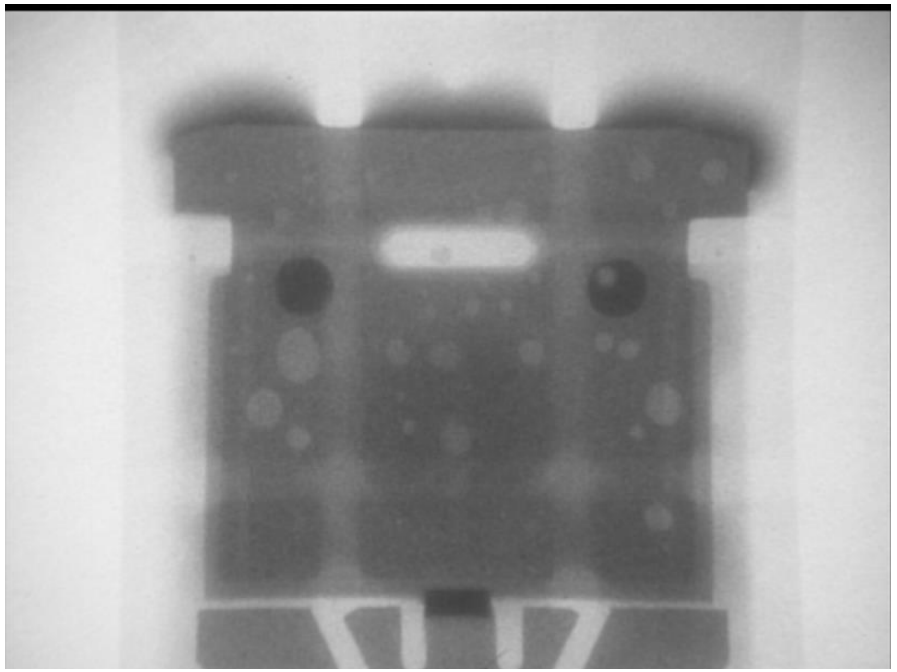
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

All next gen LMPA show Low voiding

LMPA



SAC305

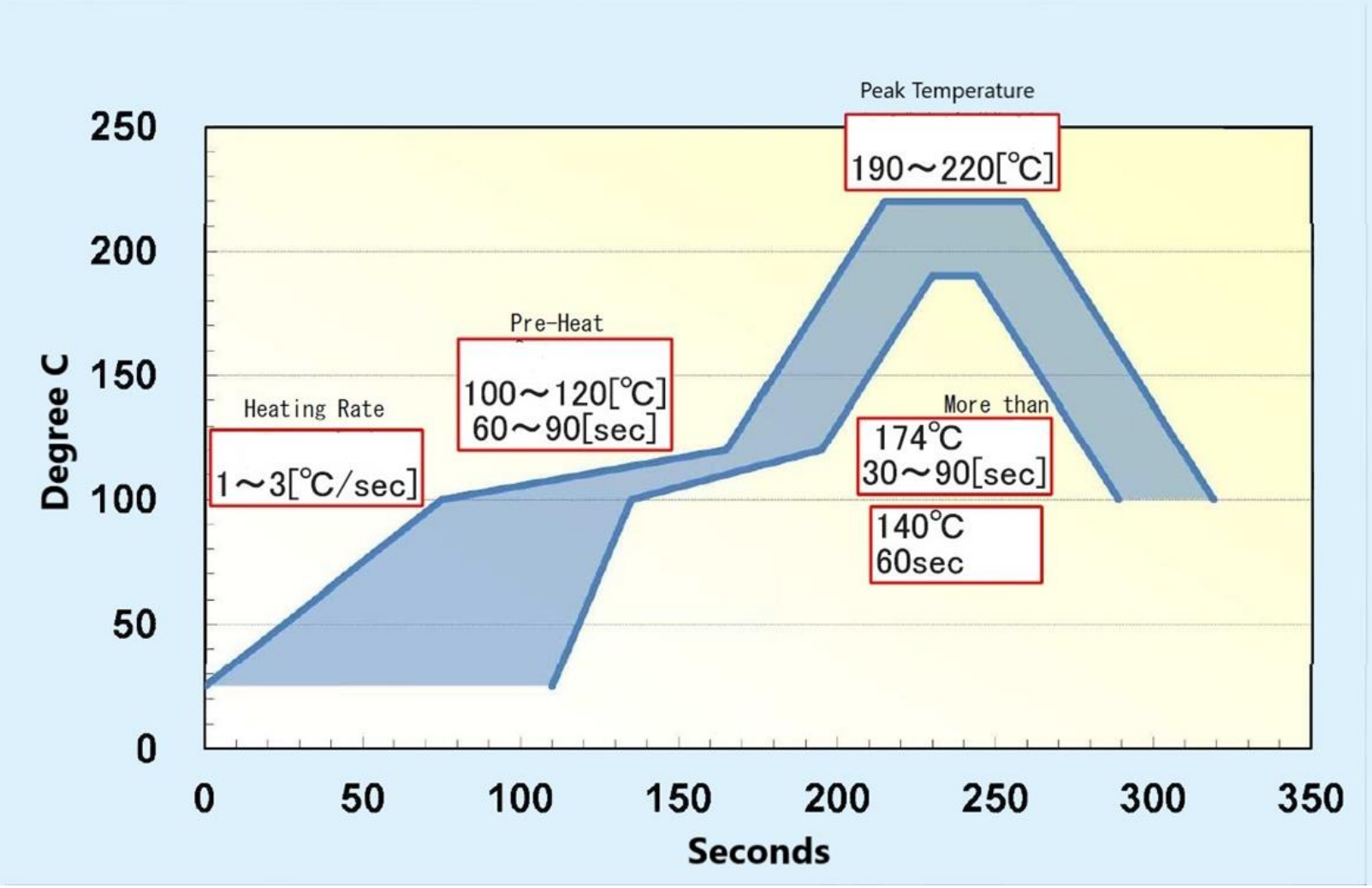


TO-252 / DPAK

AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

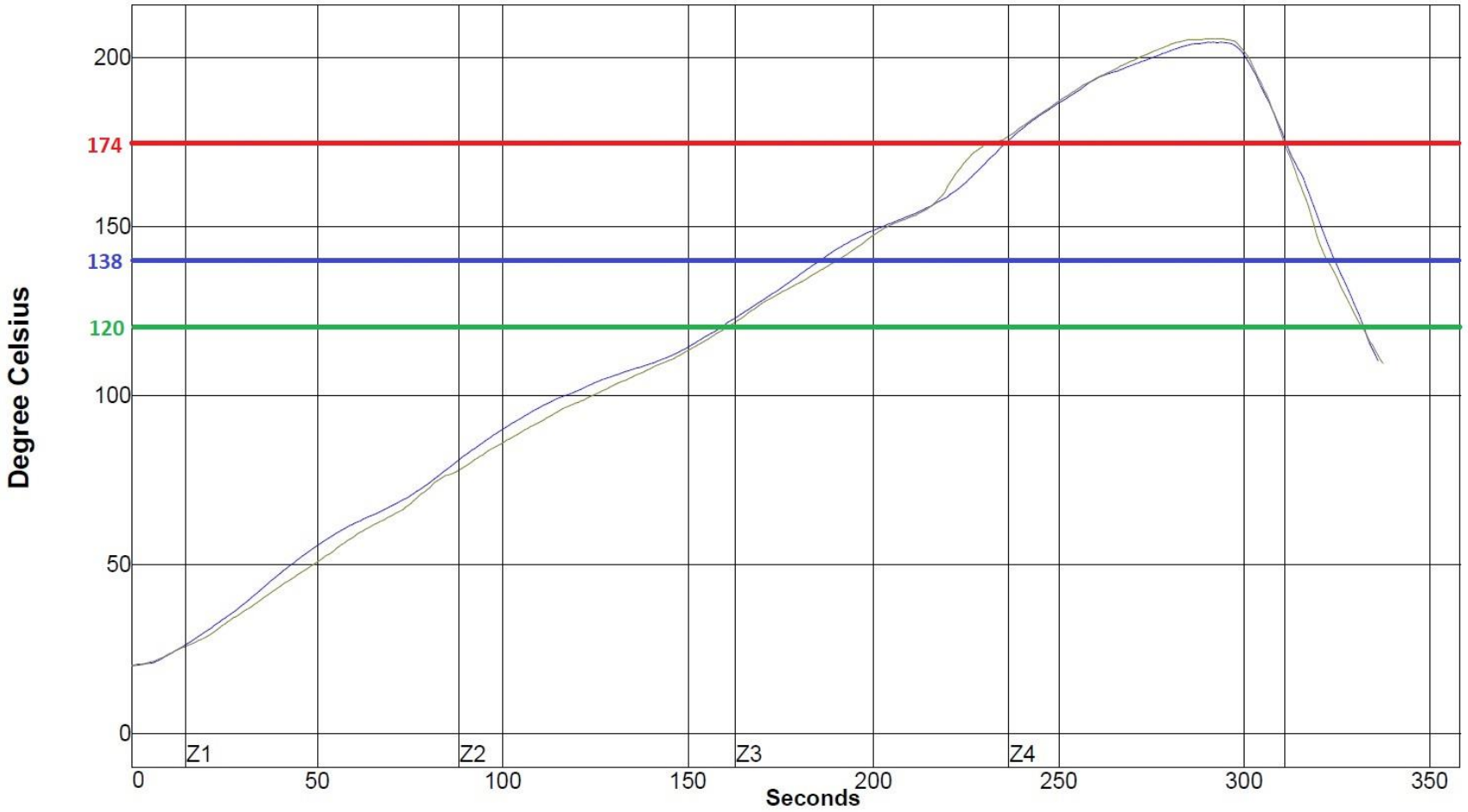
Typical LMPA reflow profile



AQC

17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

LMPA recommend reflow cooling parameters



Cooling rate +- 4C/sec

Exit temperature <120C

AQC
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

Next gen LMPA limitations

- Maximum application temperature 100C – 120C
- Thermal conductivity lower as traditional lead-free alloys
- Reliability lower or equal as traditional lead-free alloys
- Not ductile
- Large melting range instead of eutectic

AQC
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

LMPA Summary

- The use of temperature sensitive packaging materials and substrates
- The use of cheaper packaging materials and substrates
- Excellent wetting
- Low voiding
- No glue required in double side reflow applications using mixed technology (First reflow SAC305, Second reflow LMPA).
- Less or no discoloration of low cost white soldermask
- Reduce energy consumption

AQC
17 MEI 2022
EVOLUON EINDHOVEN
D&E event 2022

REFERENCES

- *Scott Mokler et al. ”The Application of Bi-Based Solders for Low Temperature Reflow to Reduce Cost While Improving SMT Yields in Client Computing Systems.” Proceedings of the SMTA International Conference, 2016*
- Keith Sweatman, “optimizing solder alloy compositionfor low temperature assembly” *Proceedings of the SMTA International Conference, 2019*
- Balverzinn GmbH, R&D
- Nihon Superior Co., Ltd, R&D

Thank you for your attention

AQC b.v.
Zuiddijk 5
5705 CS Helmond, The Netherlands
Phone: +31 88 0045500
E-mail: sales@aqcbv.com

Henk Mathijssen
Quality manager
Certified IPC-A-600 Specialist