2020 IEEE REPP Symposium
Reliability for Electronics and Photonics Packaging

12-13 November 2020
San Jose, US

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IMPROVING THE QFN BOARD LEVEL RELIABILITY USING LOW MELTING TEMPERATURE LMPA-Q SOLDER

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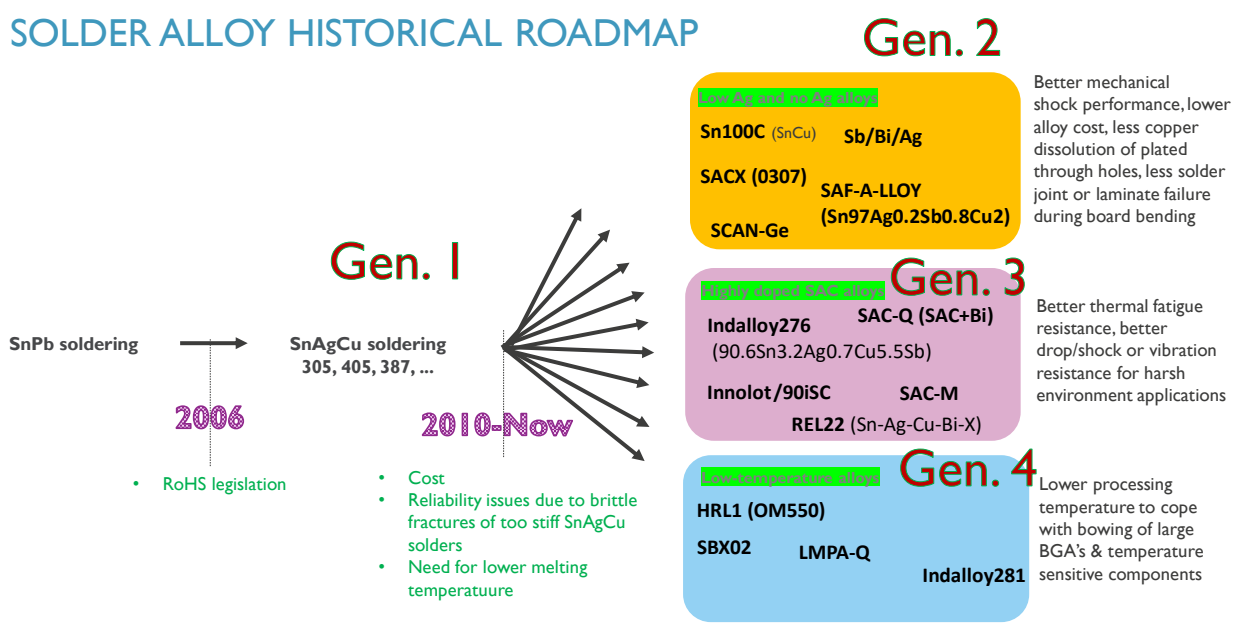
1

SOLDER ALLOY HISTORICAL ROADMAP



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2

SNBI BASED SOLDER ALLOY WITH LOW MELTING TEMPERATURE

3

LMPA-Q – LOW MELTING TEMPERATURE SOLDER BASED ON SNBI

GENERATION 4 SOLDER ALLOY

- **SnBi based low melting point alloy**
- **Solidus**: 139°C **Liquidus**: 176°C
- **Enhanced mechanical properties** compared to SnBi(Ag)
- **Eliminate problems and failures** related to high temperatures used in standard lead-free processes
- Suitable for **Reflow soldering, Wave soldering, Selective soldering**
- **Cost reduction**

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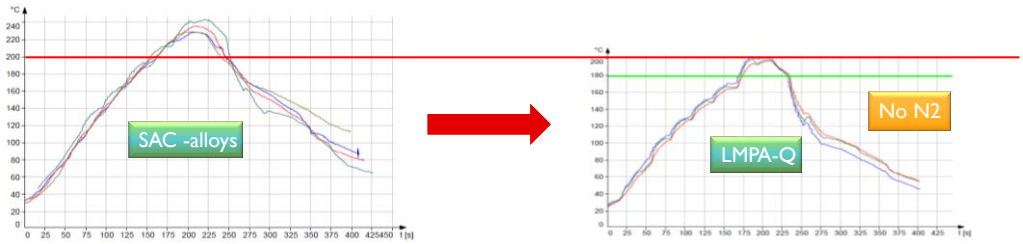
REFLOW PROFILE

~50°C LOWER REFLOW TEMPERATURE USING LMPA-Q



- Maximum reflow temperature can be reduced to 200°C

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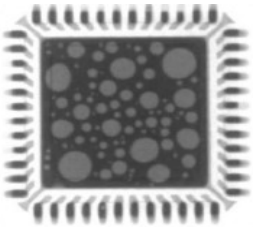
ASSEMBLY WITH LOW MELTING TEMPERATURE ALLOY (LMPA-Q)

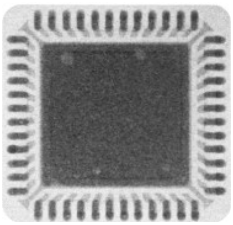
6

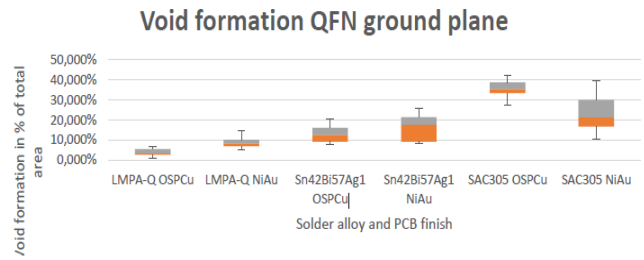
VOID FORMATION

SAC305



SnBi (LMAP-Q)





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LMPA-Q – LOW MELTING TEMPERATURE SOLDER BASED ON SNBI

Lower process temperatures : Why?

Lower stress on components

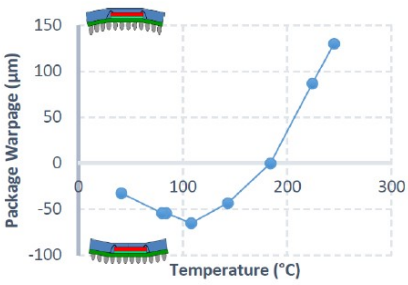
BGA warping

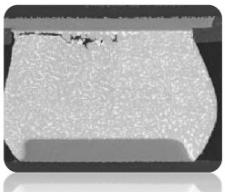
LED's

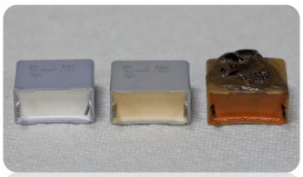
Elco's, capacitors

Plastic body components

...







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8

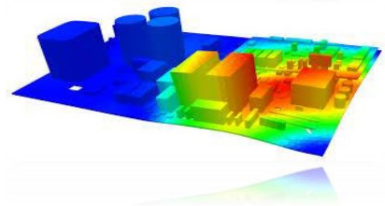
LMPA-Q – LOW MELTING TEMPERATURE SOLDER BASED ON SNBI

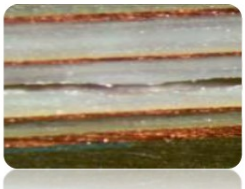
Lower process temperatures : Why?

Lower stress on PCB

Less Warping

No more 'over-TG' related issues





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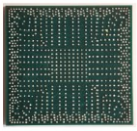
9

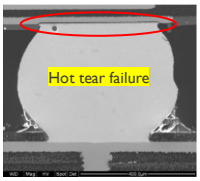
REDUCED HOT TEAR & HEAD-IN-PILLOW FAILURES FOR FINE PITCH BGA COMPONENT

Fine pitch FC-BGA component
(23x24 mm², 855 balls, 0.5 mm pitch)

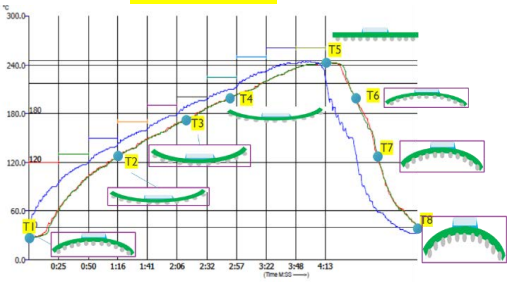


Hot tear and HIP failures experienced after solder reflow assembly

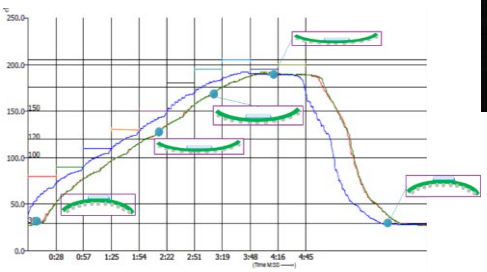
	SnAg3Cu0,5 T_{reflow} = 245°C	LMPA-Q T_{reflow} = 200°C	LMPA-Q T_{reflow} = 190°C
Total number of assembly failures	126/855	56/855	17/855
Permanent deformation after 1 x reflow	40 µm	20 µm	0 µm



Tmax = 245°C



Tmax = 190°C



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Teliszewski, S.; Lauwaert, R. and Vandevelde, B. Effect of a ductile, low melting point alloy on the hot tear defect on lead-free ball grid arrays. In: SMTA International. SMTA, 2020. pp.#454; (28-30 September 2020; Chicago, USA.)

10

ALSO POSSIBLE TO SOLDER BGA'S WITH SAC SOLDER BALLS

Tmax = 180°C

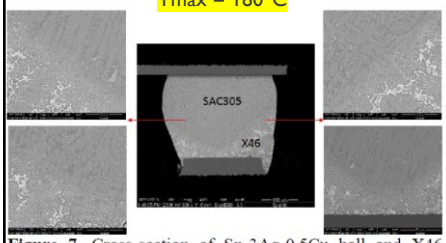

Figure 7. Cross-section of Sn-3Ag-0.5Cu ball and X46 solder paste assembled at 180°C.

Tmax = 190°C

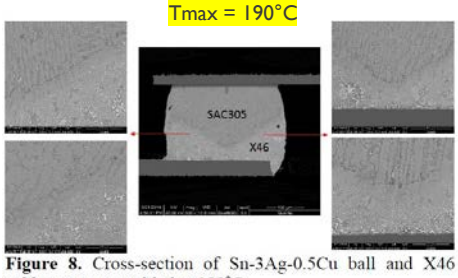

Figure 8. Cross-section of Sn-3Ag-0.5Cu ball and X46 solder paste assembled at 190°C.

Tmax = 200°C

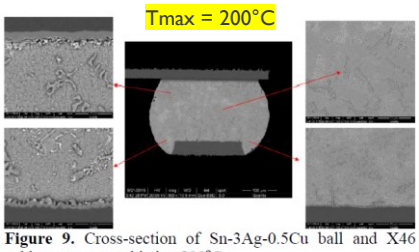

Figure 9. Cross-section of Sn-3Ag-0.5Cu ball and X46 solder paste assembled at 200°C.

Morgana Ribas, Ph.D., Anil Kumar, Divya Kosuri, Raghu R. Rangaraju, Pritha Choudhury, Suresh Telu, Siuli Sarkar, LOW TEMPERATURE SOLDERING USING SN-BI ALLOYS, SMTA 2017

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20

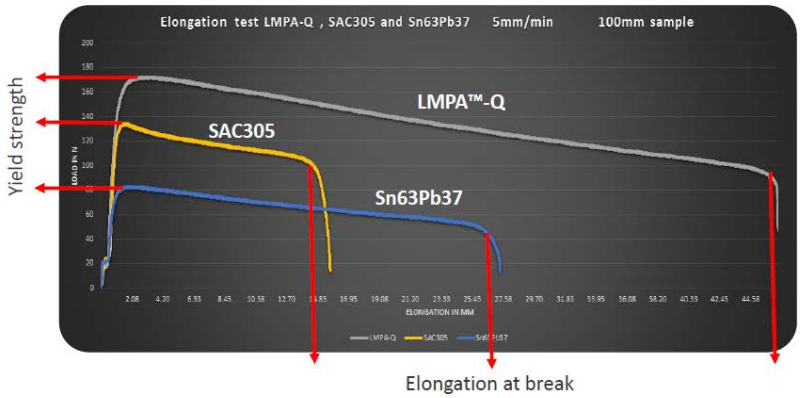
11

PHYSICAL PROPERTIES OF LOW MELTING TEMPERATURE ALLOY (LMPA-Q)

12

MECHANICAL PROPERTIES

Elongation test



→ Instron 5542

→ LMPA™-Q , SAC305 , Sn63Pb37

→ solid wire: dia: 2mm L: 100mm

→ Elongation speed : 5mm/min

Solder Alloy	Start Length	Length at failure	Elongation at failure
LMPA-Q	100mm	146.45mm	46.45%
SAC305	100mm	115.70mm	15.70%
Sn63Pb37	100mm	127.39mm	27.39%

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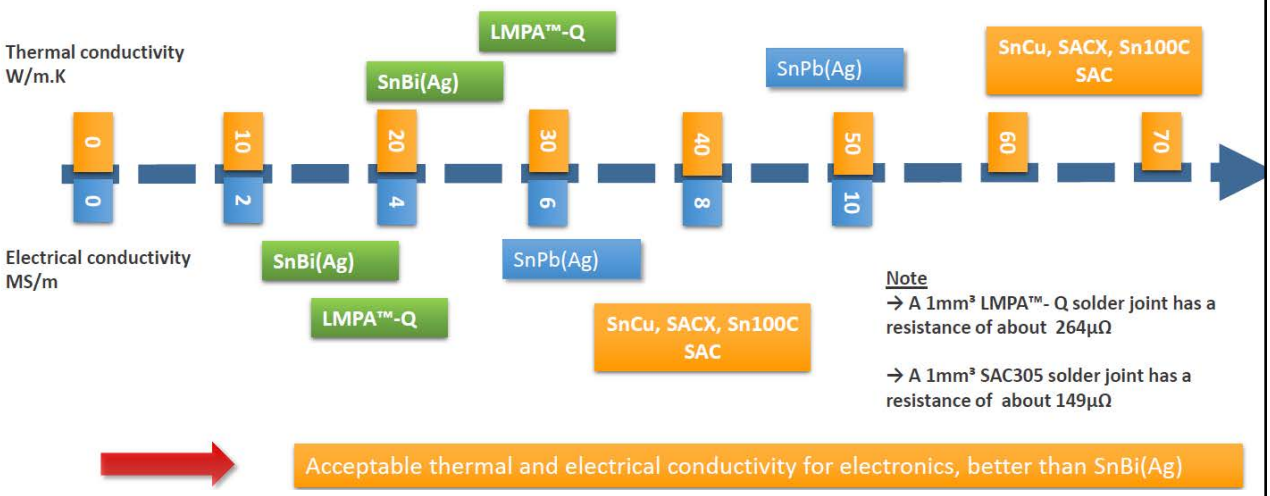
13

Thermal and electrical conductivity



Note

→ A 1mm³ LMPA™- Q solder joint has a resistance of about 264µΩ

→ A 1mm³ SAC305 solder joint has a resistance of about 149µΩ

Acceptable thermal and electrical conductivity for electronics, better than SnBi(Ag)

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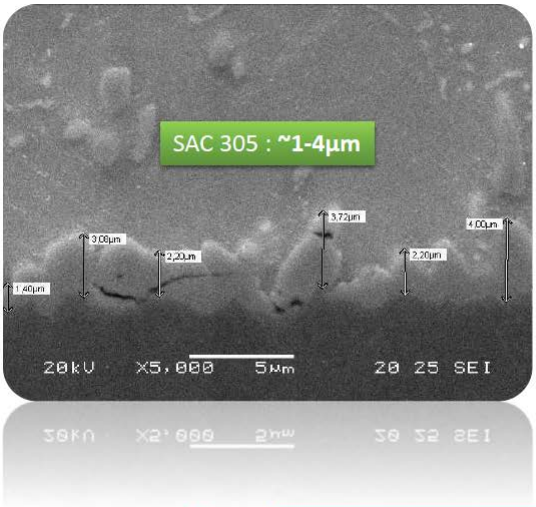
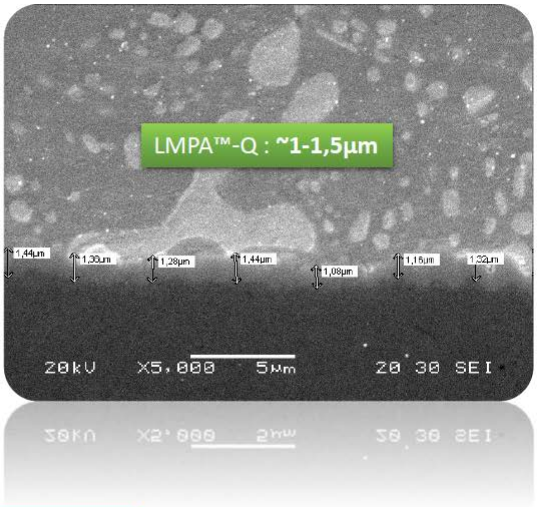
14

Intermetallic thickness on Cu





Lower intermetallic thickness, no micro-cracks

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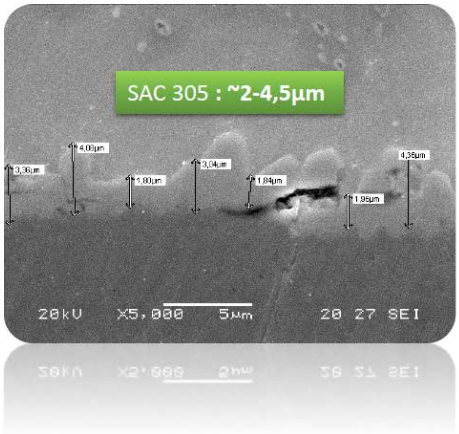
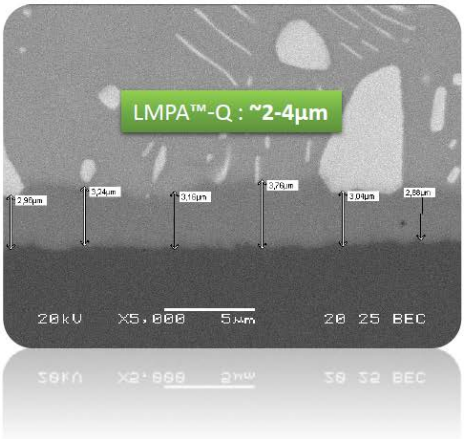
Ageing: 1000H@85°C





Acceptable intermetallic growth and grain coarsening, no micro-cracks

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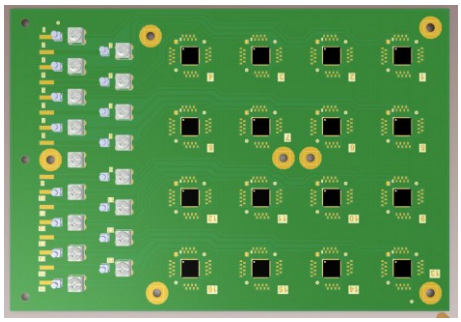
16

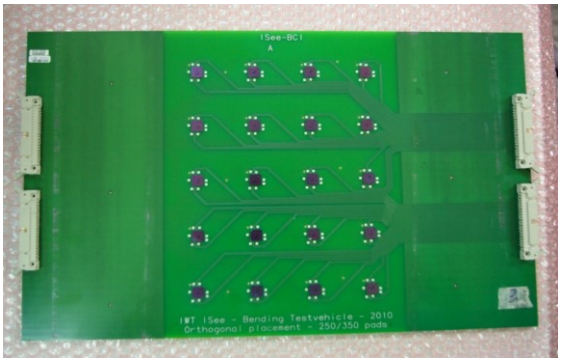
FATIGUE CYCLING ANALYSIS

17

TEST DESCRIPTION

- Component:
  - QFN 9x9 mm
    - Mold 1: CTE = 7 ppm/°C
    - Mold 2: CTE = 15 ppm/°C
  - Daisy Chain component
- PCB:
  - 1.6 mm thick FR4
- Test condition:
  1. Thermal Cycling: -40°C to +125°C
  2. Bending cycling: 3 mm displacement @ 125°C
- Measurement:
  - In situ resistance measurement





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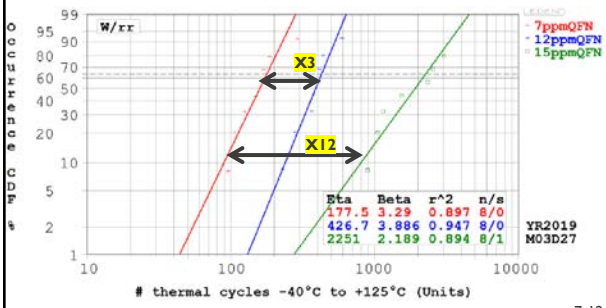
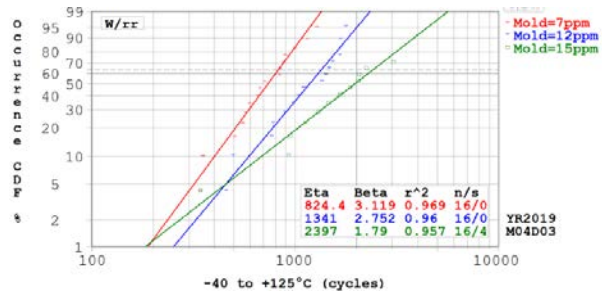
18

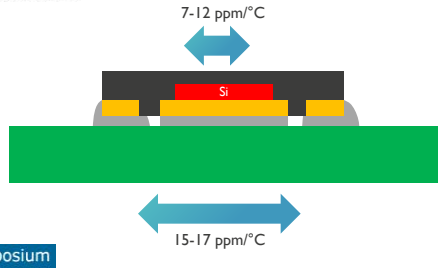
IMPACT OF MOLD CTE ON QFN RELIABILITY

Small Exposed pad size – rigid PCB



Large Exposed pad size – more flexible PCB





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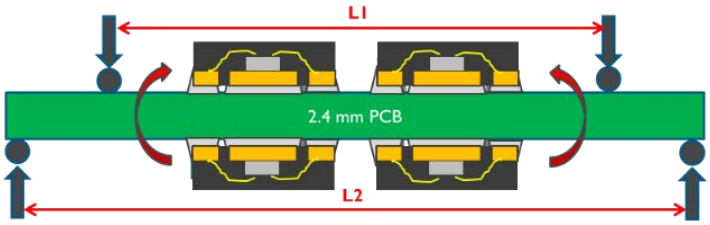
19

FOUR POINT BENDING EXPERIMENT



- Equal stress in the area between the inner bars
- Similar shear loading as with thermal cycling
- Test performed at fixed temperature

Vandevelde, B.; Vanhee, F.; Pissoort, D.; Degrendele, L.; De Baets, J.; Allaert, B.; Lauwaert, R.; Zanon, F.; Labie, R. and Willems, G. Four-point bending cycling: The alternative for thermal cycling solder fatigue testing of electronic components. Microelectronics Reliability. Vol. 74: 131-135; 2017.

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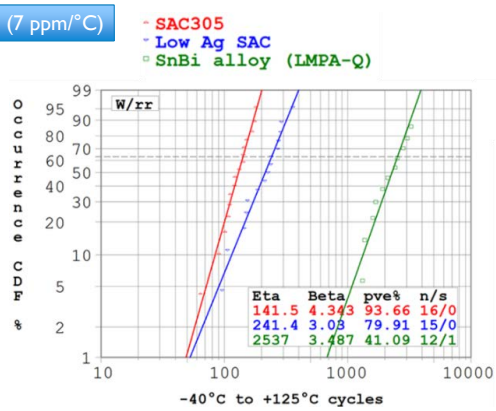
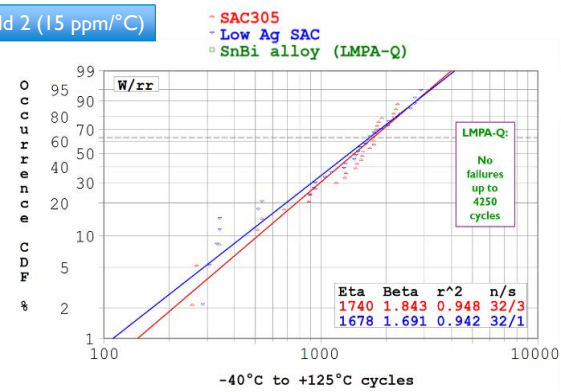
20

RESULTS
THERMAL CYCLING -40°C TO +125°C

Mold 1 (7 ppm/°C)



Mold 2 (15 ppm/°C)



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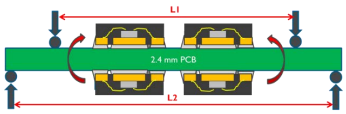
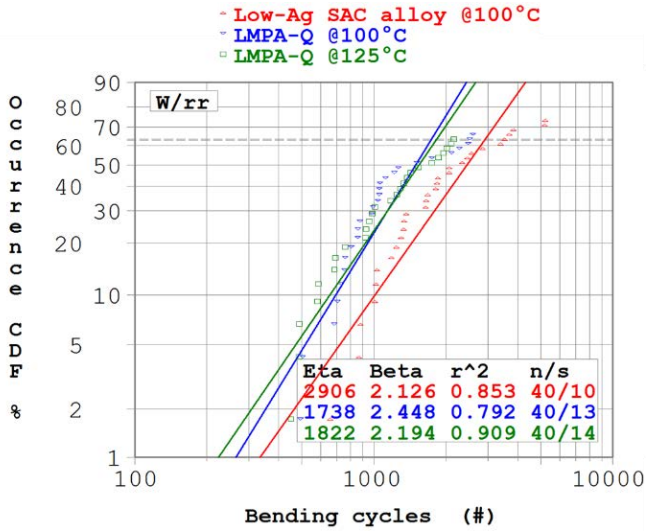
21

RESULTS
4PT BENDING CYCLING





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OVERVIEW OF TEST RESULTS

Thermal cycling

	QFN's with mold 1 (7 ppm/°C)	QFN's with mold 2 (15 ppm/°C)
SAC305	N63% = 141	N63% = 1740
SACX	N63% = 241	N63% = 1678
LMPA-Q (SnBi)	N63% = 2537	No failure up to 4250 cycles

Bending cycling

	Test performed at 100°C	Test performed at 125°C
SACX	N63% = 2907 cycles	Not tested
LMPA-Q (SnBi)	N63% = 1738 cycles	N63% = 1822 cycles

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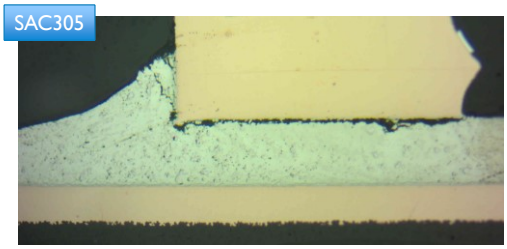
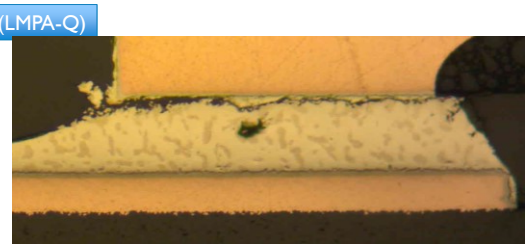
23

FAILURE ANALYSIS

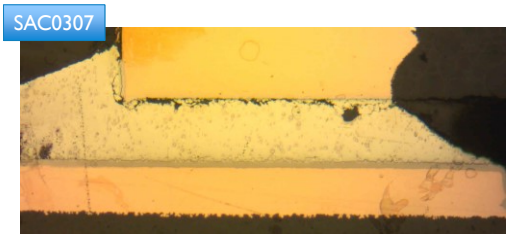
SAC305

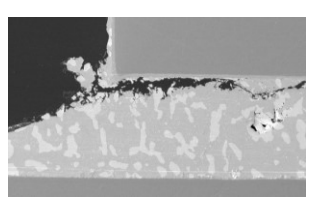


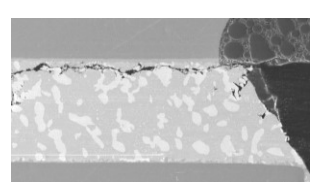
SnBi (LMPA-Q)



SAC0307







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24

OTHER RELIABILITY TESTS

25

Vibration testing

→ High accuracy measuring device : SMD reflow soldered with DP 5600 LMPA™
Through hole hand soldered with LMPA™ solder wire.

→ BS EN 60945: Section 8.7.2. .
BS EN 60068-2-6: 2008. Part 2-6.Test Fc.

→ Resonance search
- 5Hz and up to 13.2Hz with a displacement of +/-1mm.
- 13.2Hz and up to 100Hz with constant maximum acceleration of 7m/s² (0.7g)
- testing in X, Y and Z axis

→ Vibration Endurance.
- 2 hour endurance test at the noted resonant points or at 30Hz if Q<5

→ X : 2hrs at 82,92HZ, 3g pk acceleration
→ Y : 2hrs at 30HZ, 3g pk acceleration
→ Z : 2hrs at 30HZ, 3g pk acceleration

→ **The units exhibited no signs of damage or misalignment after the vibration test.**

→ **ICT and functional test after vibration test: pass**

Result : Pass

26

Destructive comparative vibration testing : LMPA™ vs SAC305

→ High accuracy measuring device : SMD reflow soldered **with DP 5600 LMPA™ and SAC 305**
Through hole hand soldered with LMPA™ solder wire and SAC 305

→ X-axis 30min vibration endurance

X-axis 30min vibration endurance				
Test sequence	Frequency	Acceleration	LMPA™	SAC 305
1	30Hz	18g	Pass	Pass
2	30Hz	20g	Pass	Pass
3	30Hz	21g	Pass	Pass
4	30Hz	22g	Pass	Pass
5	50Hz	25g	Pass	Fail

SAC 305 solder joint failur

SAC 305 fails first

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27

Shock testing

→ High accuracy measuring device: SMD reflow soldered with DP 5600 LMPA™
Through hole hand soldered with LMPA™ solder wire.

→ BS EN 60068-2-27: 2009. Part 2-27. Test Ea. Shock.

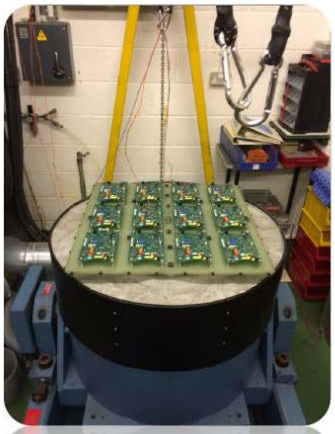
→ 3 Shocks in each direction (pos./neg.) of 3 axes : 18 shock in total

→ X: Peak Acceleration of 10g(*) Half Sine with a pulse width of 11 milliseconds.
Y: Peak Acceleration of 30g Half Sine with a pulse width of 11 milliseconds.
Z: Peak Acceleration of 30g Half Sine with a pulse width of 11 milliseconds.
* 10g in X was used because more force disconnected the sensor from the measuring setup

10 g is about 4X the force a mobile phone experiences when dropping from 1 m on a concrete floor.

→ The units exhibited no signs of damage or misalignment after the shock test.

→ ICT and functional test after shock test: pass



Result : Pass

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28

CONCLUSIONS

29

CONCLUSIONS & FUTURE

Conclusions:

- SnBi based low melting temperature solder LMPA-Q has large benefits in processability and cost
- Reliability tests for large QFN component show up to 12 times higher life time than for SnAgCu solder
- Vibration and shock reliability tests show similar life time as for SnAgCu

Future:

- Further testing need to be done to fully confirm the improved reliability, also for other components
- Material characterisation for creep behaviour and fatigue empirical law

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30

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31