Durafuse™ HT

A Drop-in High-Temperature Pb-free (HTLF) Solution that Outperforms High-Pb Solders

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About the Presenter

Dr. HongWen Zhang

R&D Manager, Alloy Group

- 40+ papers and journal articles
- Two Book Chapters in Soldering and Sintering
- PhD in Material Science and Engineering, and a Master's degree in Mechanical Engineering
- Lean Six Sigma Green Belt
- Certified SMT Process Engineer
- Certified IPC Specialist for A-600 and IPC-A-610D
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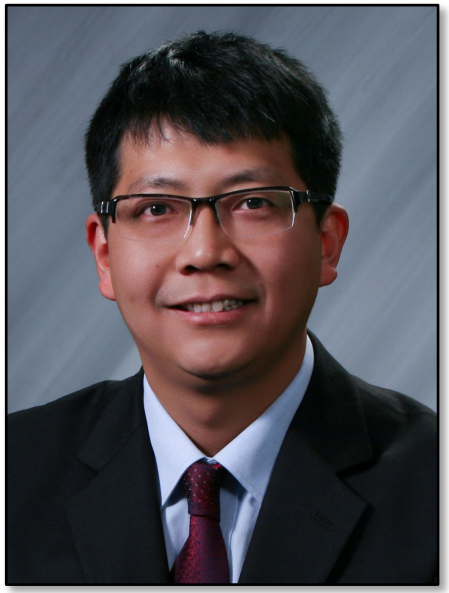
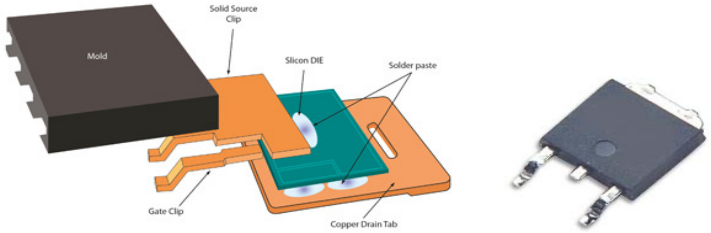
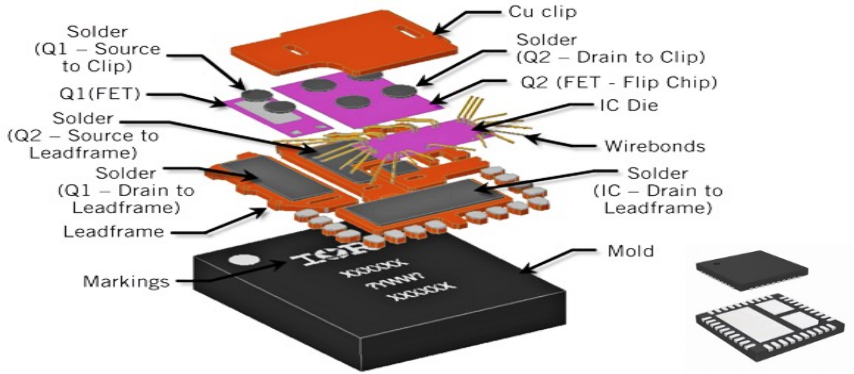


Die-Attach in Power Discrete





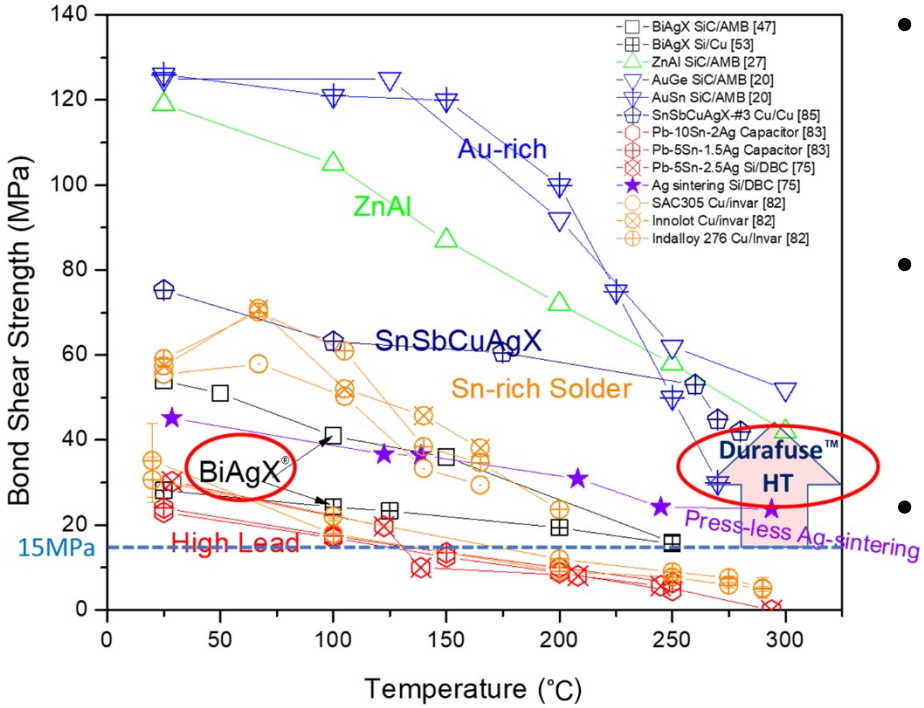
High lead solders are commonly used for die attachment. Both printing and dispensing solder pastes are used for die attach and clip bond

Lead will be regulated in electronics industry due to the harmful impact on human health and environment although high lead exemption being extended to 2024

Discrete Power Components will be bonded onto a PCB in the subsequent SMT reflow, which requires the internal Die-Attachment surviving 260°C SMT reflow temperature multiple times and no significant degradation of the electrical or even the thermal performance.

http://powerelectronics.com/pmics/25-pol-regulator-shrinks-pcb-size-20

HTLF DA Materials



All HTLF bonding materials are *stronger* than high-Pb

- **Durafuse™ HT Solders** *(Patent-Pending)*
  - Die-attach in power discretes
  - Softening point of >280°C
  - Thermal and electrical conductivity ≥ High-Pb
- **BiAgX® Solders** *(Patented)*
  - Die-attach in power discretes
  - Remelting temperature >262°C
  - Thermal and electrical conductivity ≤ High-Pb
- **Ag-Sintering Materials**
  - Die-attach in power modules
  - Melting temperature >900°C
  - Thermal and electrical conductivity >> High-Pb

Durafuse™ HT and BiAgX® are designed with Durafuse™ technology

Durafuse™ HT*

*(*Patent Pending*)

Durafuse™ is a mixed-alloy solder technology

SnSb-based alloy

- High-melting temperature (>300°C)
- Good HT shear strength
- Thermal conductivity >34W/mK
- Rigid and brittle

+

Sn-rich solders

- Low-melting temperature (217°C to 245°C)
- Thermal conductivity ~40 to 60W/mK
- Ductile and good strength up to 175°C

Design criteria of Durafuse™ HT

Combining the merits of and compensate for the weakness of both constituents

- **Softening temperature >280°C**
  - Strength >> High-Pb @ 280°C
  - **DA5: Strength ≥15MPa**
- **Thermal and electrical properties**
  - ≥ High-Pb
    - **Thermal conductivity >34W/mK**
    - **Electrical resistivity 1.6~2.06E-5 (ohm-cm)**
- **Temperature Cycling Test**
  - ≥ High-Pb
- **Drop-in process**
  - Compatible to High-Pb Process

Durafuse™ HT Processability

Indium7.28 flux for printing and dispensing

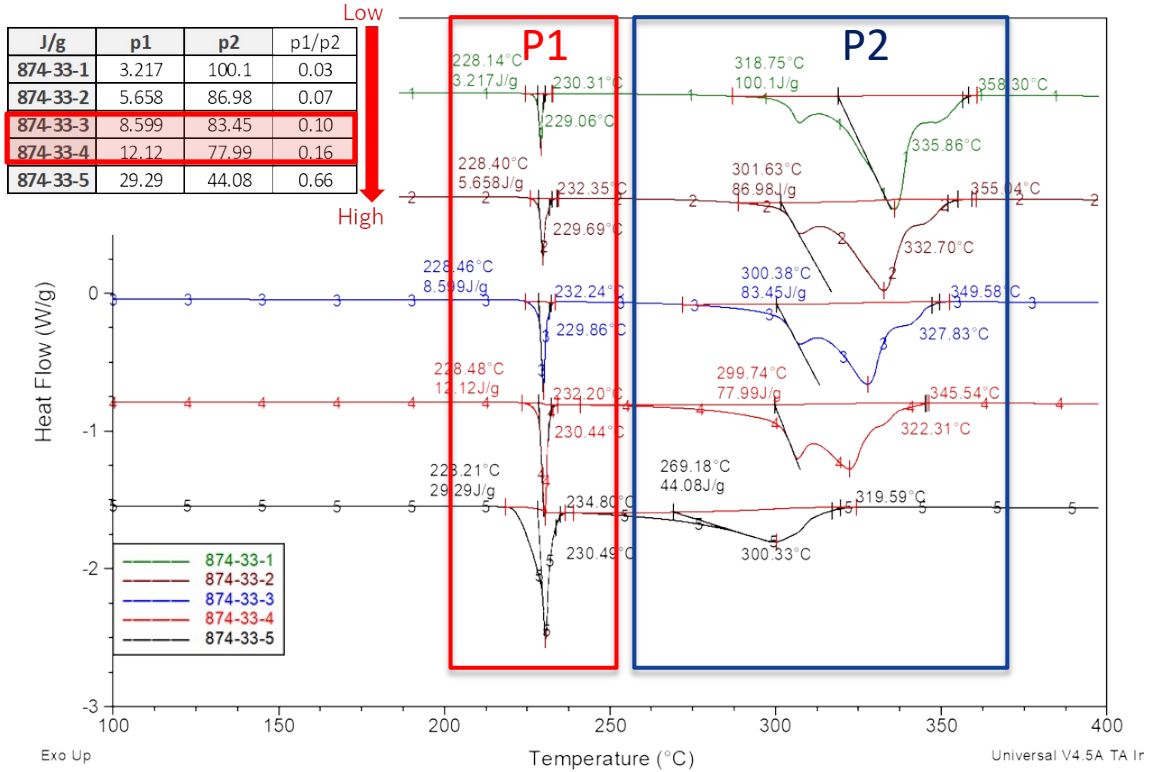
- Internal printing test up to 8 hours for T4 (88wt%)
- Internal dispensing test based on T4 100g/30cc syringe with 23G needle, up to 4 hours (84wt%)

Flux residue cleanability

- Cleaning solutions well-established:
  - Kyzen
  - Zestron

Durafuse™ HT – DSC

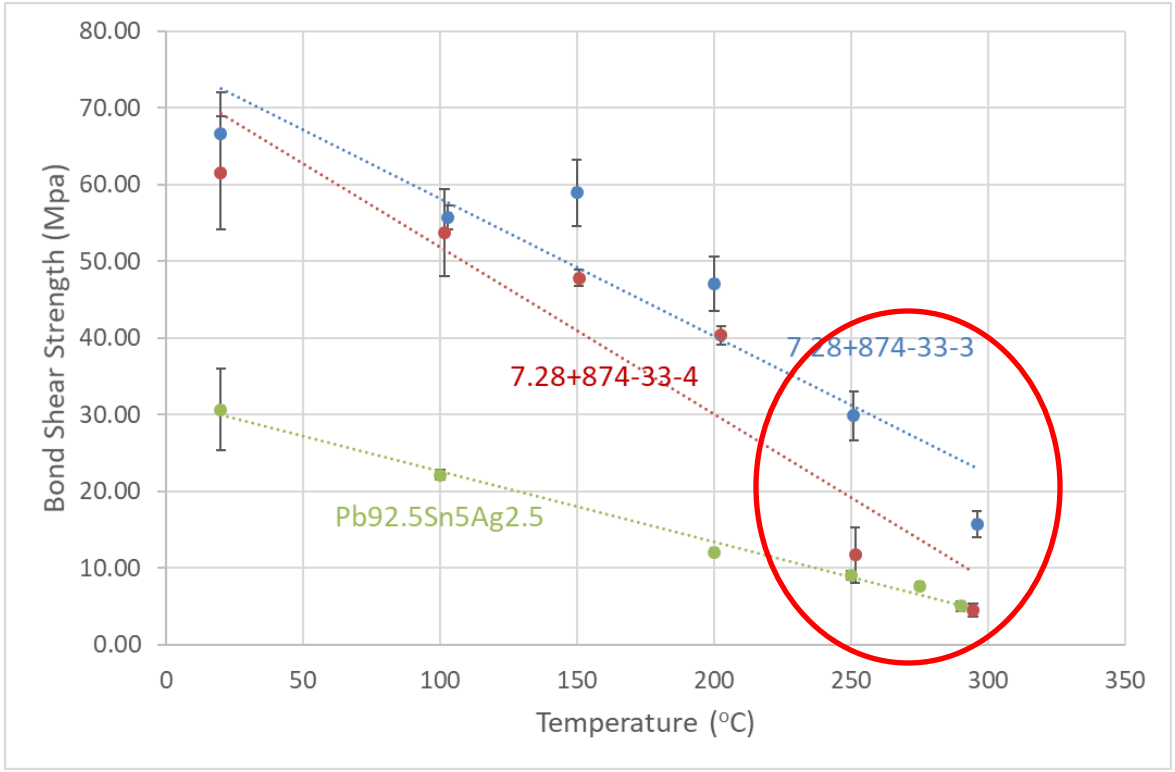
J/g	p1	p2	p1/p2
874-33-1	3.217	100.1	0.03
874-33-2	5.658	86.98	0.07
874-33-3	8.599	83.45	0.10
874-33-4	12.12	77.99	0.16
874-33-5	29.29	44.08	0.66



- **Ratio of P1 to P2** from DSC indicates the ratio of low-melting Sn-richphase relative to high-melting SnSb phase
- **Controlled** low-melting Sn-rich phase in the final joint

Low-melting phase does exist

Durafuse™ HT Shear Strength



- **874-33-3** maintains HT shear strength around 15MPa even above 290°C.
- **874-33-4** decreases the HT shear strength similar to Pb92.5Sn5Ag2.5 when temperature rises above 250°C
- 874-33-3, 874-33-4 and Pb92.5Sn5Ag2.5 have been selected for TCT

3x3mm^2 Cu die on Cu substrate, reflowed at 340°C actual peak temperature

Durafuse™ HT Reliability

Reliability (TC)

- TCT -40 to 150°C done for 3000c
  - TiNiAgSi die (5 x 5mm² x 0.15mm) on Cu substrate
  - TiNiAgSi die (4.2 x 2.4mm² x 0.1mm) on Cu-leadframe
  - *TiNiAgSi die (3.93 x 1.75mm² x 0.06mm) on Cu-leadframe*
  - *TiNiAgSi die (1.8 x 1.5mm² x 0.06mm) on Cu-leadframe*
- TCT -55 to 150°C ongoing for 3000c
  - TiNiAgSi die (3.93 x 1.75mm² x 0.06mm) on Cu-leadframe
  - TiNiAgSi die (1.8 x 1.5mm² x 0.06mm) on Cu-leadframe
  - TiNiAgSi die (2.5 x 1.6 x 0.105mm) on Cu-leadframe and clip-bond
- TCT -55 to 175°C done for 1000c
  - *TiNiAgSi die (2.5 x 1.6 x 0.105mm) on Cu-leadframe (encapsulated components)*
- TCT -65 to 150°C done for 3000c
  - TiNiAgSi die (4 x 1.7 x 0.065mm) on Cu-leadframe (encapsulated components)

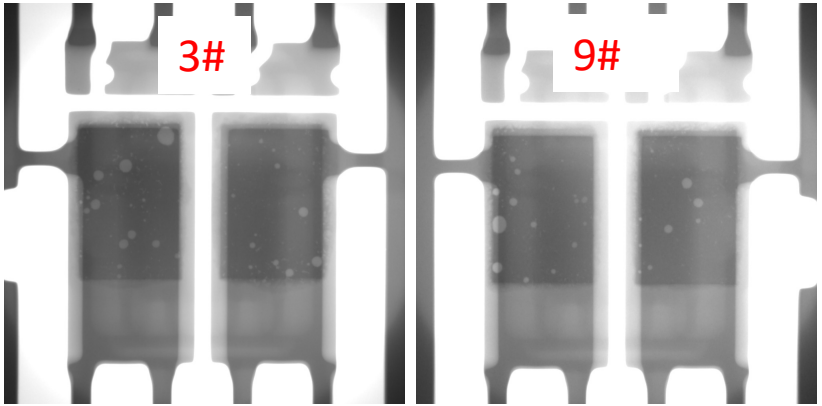
Indium Corporation internal tests

Beta-site tests: Processed under the same high-Pb production practice

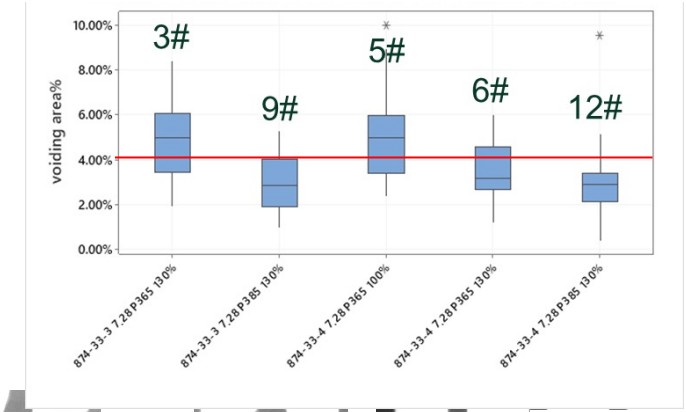
Failure Analysis

- Microstructural evolution after TCT
- SEM and EDS mapping

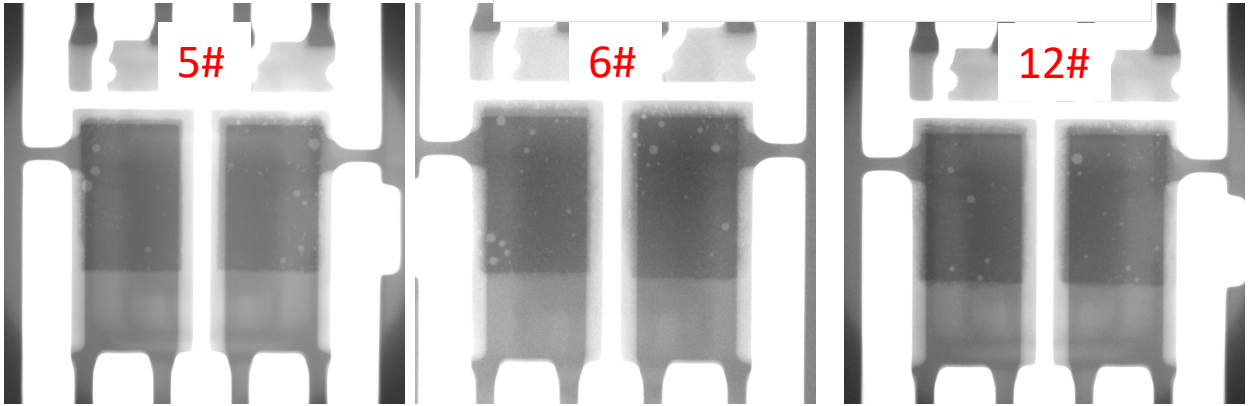
Durafuse™ HT Voiding



Clip-bond package, TiNiAg-Si die (2.5x1.6x0.105mm)



874-33-3
3#: 130%, 365°C
9#: 130%, 385°C
874-33-4
5#: 100%, 365°C
6#: 130%, 365°C
12#:130%, 385°C

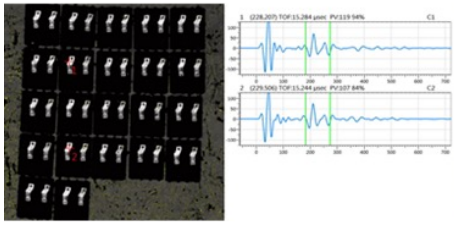


CSAM Before and After MSL1

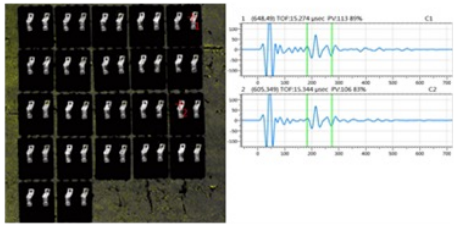
7.28+874-33-3

Clip-bond components,
TiNiAgSi die
(2.5 x 1.6mm² x 0.105mm)

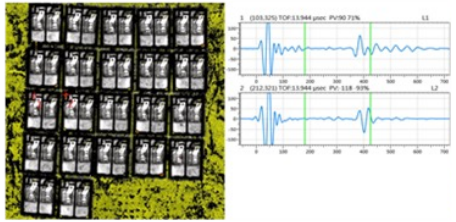
Clip 0h



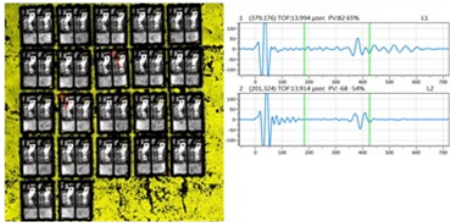
Clip After MSL1



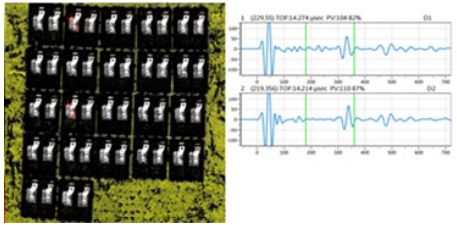
Lead 0h



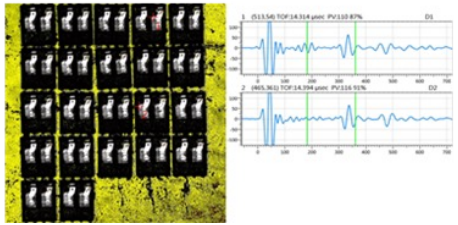
Lead After MSL1



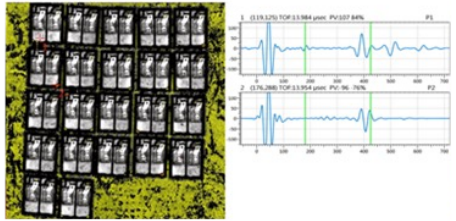
Die 0h



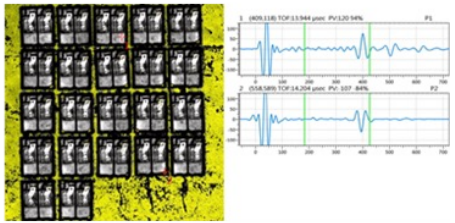
Die After MSL1



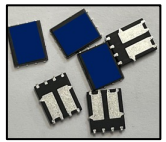
Pad 0h



Pad After MSL1

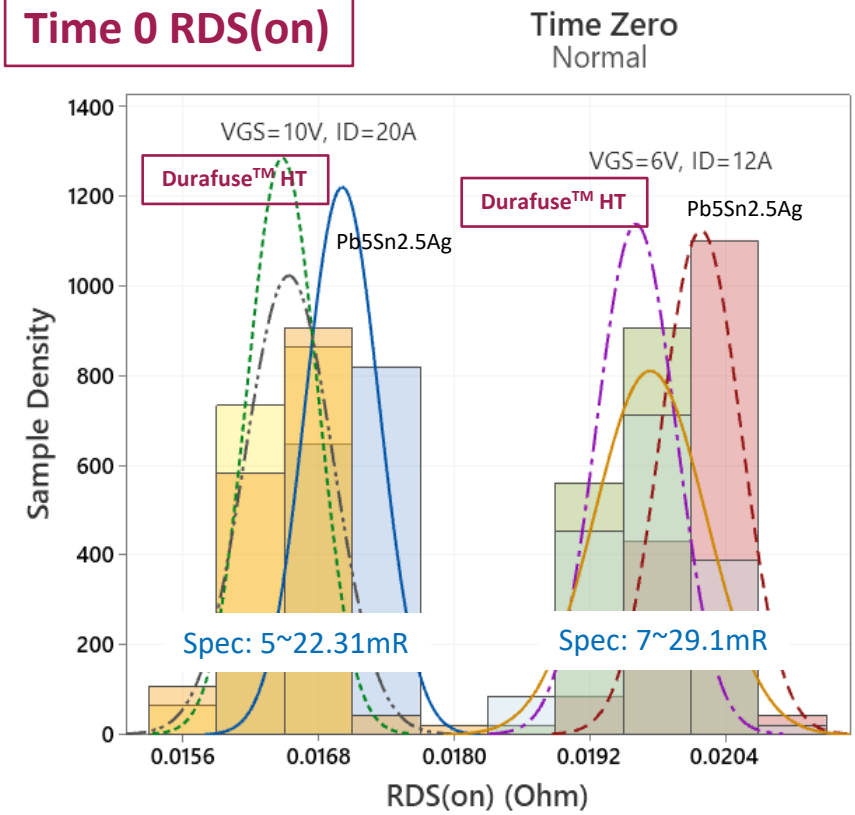


Clip-bond package assembled with 7.28+874-33-3 passed MSL1

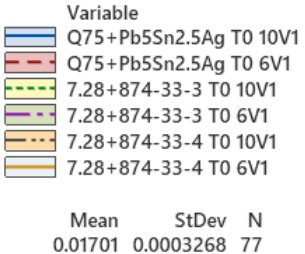


RDS(on) Time Zero

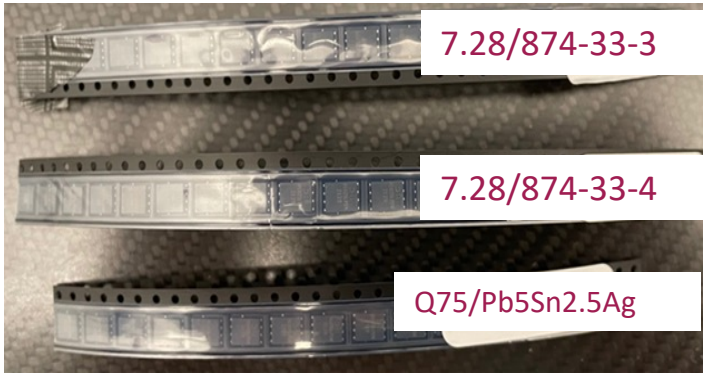
Time 0 RDS(on)

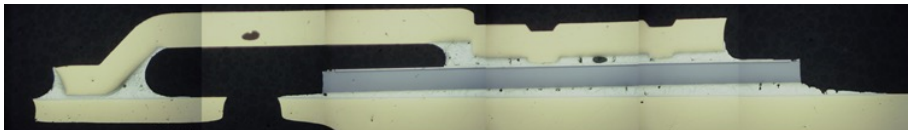


Durafuse™ HT (874-33-3 & 874-33-4) outperformed
Q75/Pb92.5 in RDS(on) before TCT

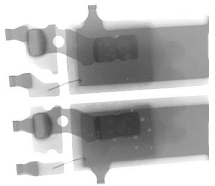


Mean	StDev	N
0.01701	0.0003268	77
0.02019	0.0003547	77
0.01649	0.0003100	77
0.01962	0.0003502	77
0.01654	0.0003895	77
0.01973	0.0004918	77





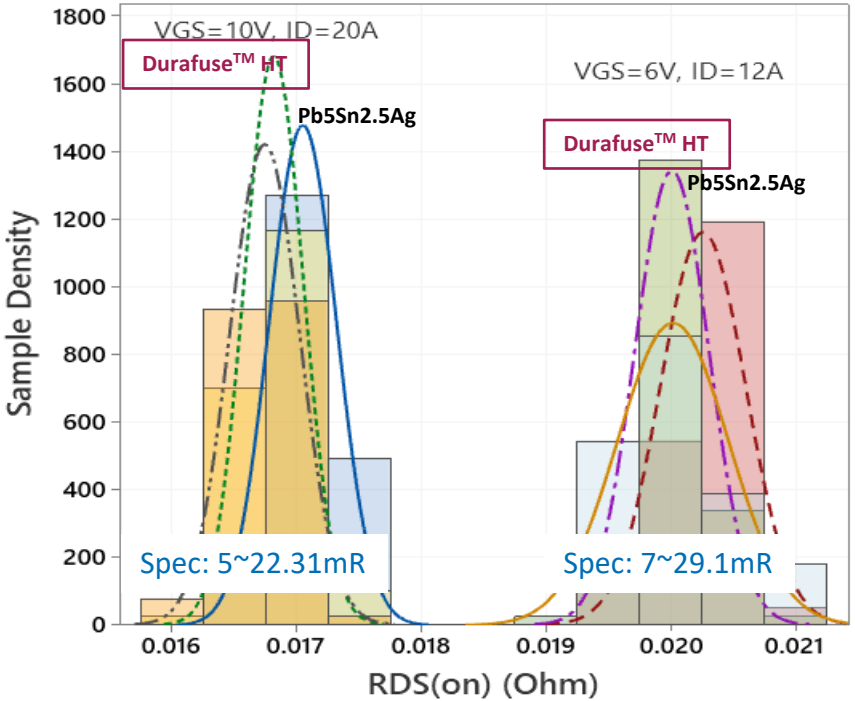
Clip-bond components,
TiNiAgSi die
(2.5 x 1.6mm² x 0.105mm)



RDS(on) After TCT -55/175°C

1000c TCT RDS(on)

After 1000c -55/175°C TCT
Normal



Variable
- Q75+Pb5Sn2.5Ag TCT 1000c 10V1_1
- Q75+Pb5Sn2.5Ag TCT 1000c 6V1_1
- 7.28+874-33-3 TCT 1000c 10V1
- 7.28+874-33-3 TCT 1000c 6V1
- 7.28+874-33-4 TCT 1000c 10V1
- 7.28+874-33-4 TCT 1000c 6V1

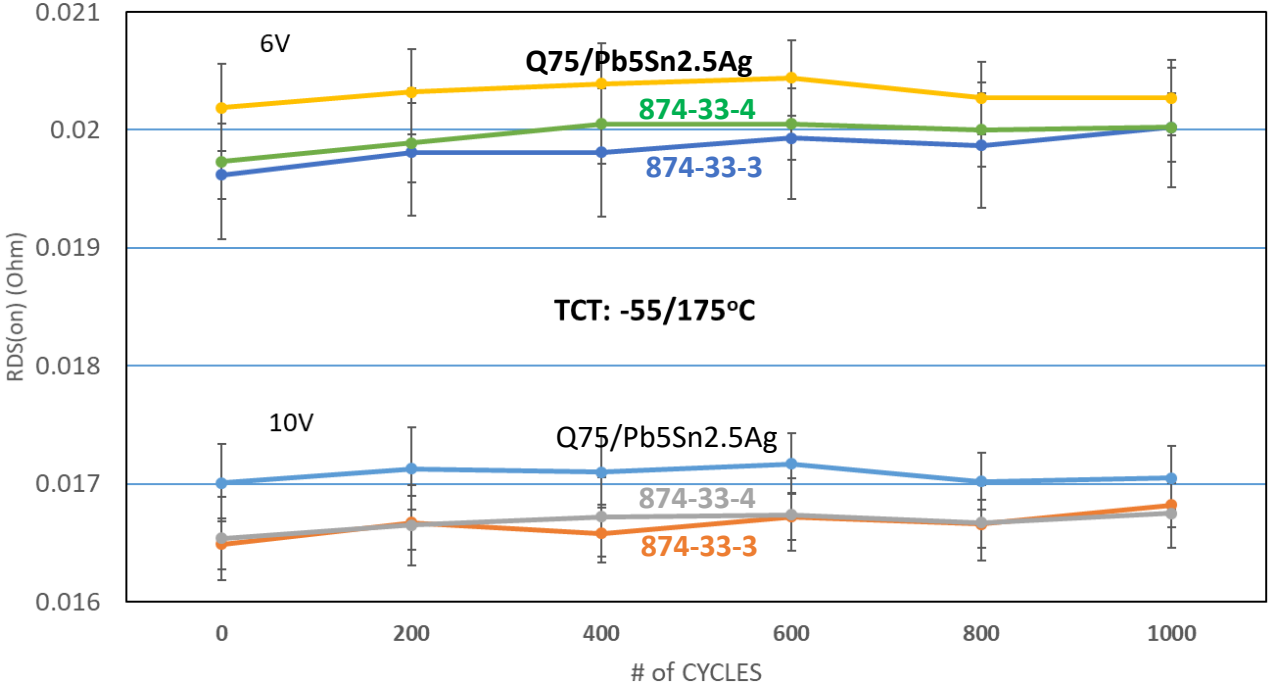
Mean	StDev	N
0.01705	0.0002701	77
0.02027	0.0003435	77
0.01682	0.0002372	77
0.02002	0.0002969	77
0.01675	0.0002806	77
0.02002	0.0004468	77

Durafuse™ HT (both 874-33-3 and 874-33-4) outperformed Q75/Pb92.5 in RDS(on) after TCT

874-33-3 has narrower RDS(on) distribution than both 874-33-4 and Pb5Sn2.5Ag

Clip-bond package,
TiNiAgSi die (2.5 x 1.6mm² x 0.105mm)

RDS(on) After TCT -55/175°C

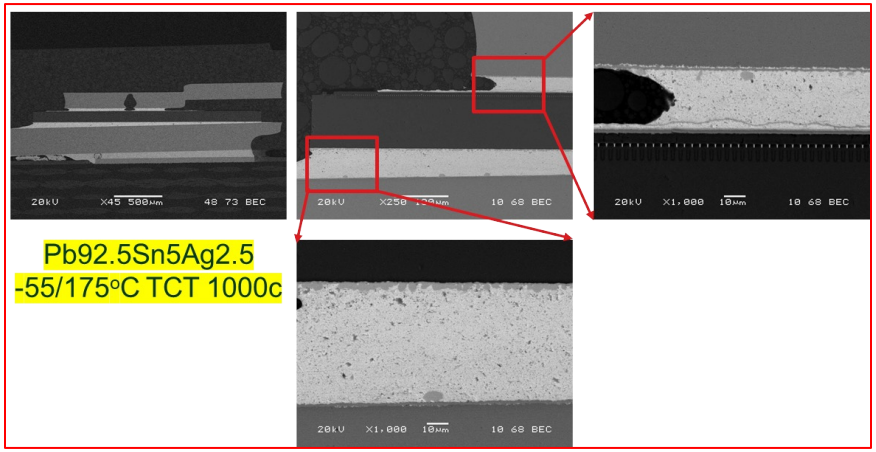


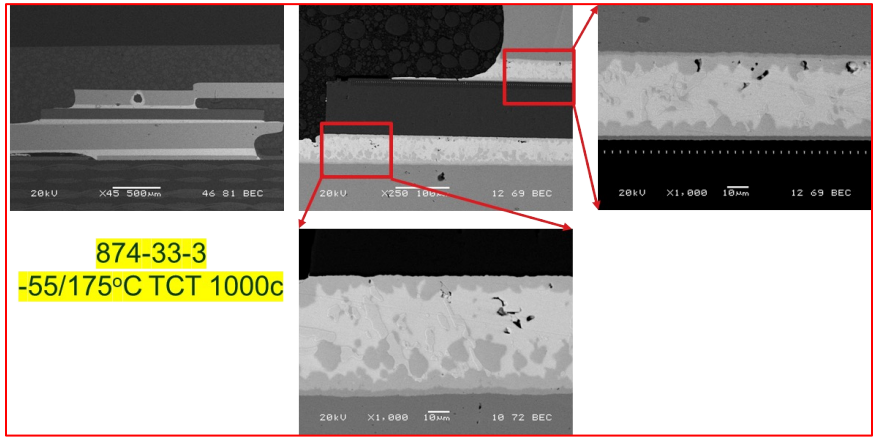
Durafuse™ HT has lower RDS(on) than high-Pb within the whole TCT

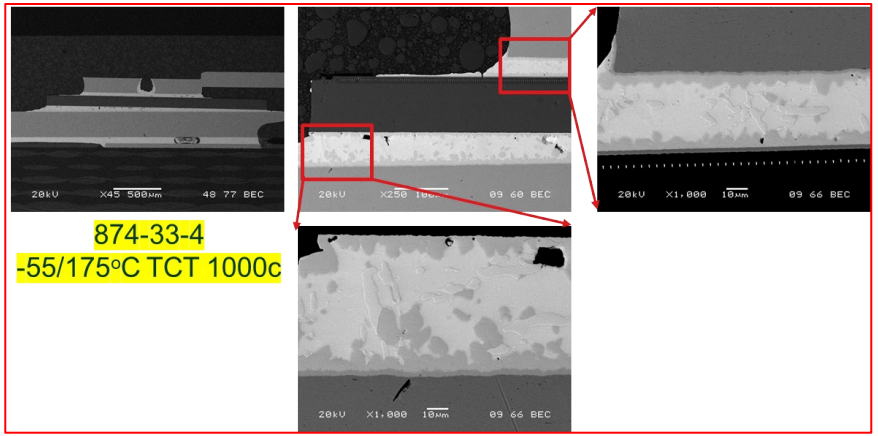
RDS(on) shifting is less than 3% for all three pastes

Clip-bond components, TiNiAgSi die (2.5 x 1.6mm² x 0.105mm)

TCT -55/175°C for 1000cycles







No Corner Crack for Hi-Pb and
two HTLF after 1000c TCT

Clip-bond components,
TiNiAgSi die
(2.5 x 1.6mm^2 x 0.105mm)

Summary

- **Durafuse™ HT** has been designed to replace high-Pb in power discrete applications
- Durafuse™ HT can be processed as **a drop-in solution** by using the current high-Pb production procedure
- Durafuse™ HT (both 874-33-3 and 874-33-4) **outperforms** high-Pb in RDS(on) before and after TCT
- Durafuse™ HT passed **MSL1**

Acknowledgement

Thank you to my Indium Corporation co-workers:

- Samuel Lytwynec, Tyler Richmond, Tybarius Harter, Dr. Huaguang Wang, and Dr. Jie Geng
- Sze Pei Lim, Leo Hu, Leon Rao, Dean Payne, and Dr. Andy Mackie
- Anne Bazan, Christian Vischi, and Jingya Huang

Questions?

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