MATERIAL AND PACKAGE RELIABILITY NEEDS / CHALLENGES FOR HARSH ENVIRONMENTS - POWER ELECTRONIC MODULE EXAMPLE

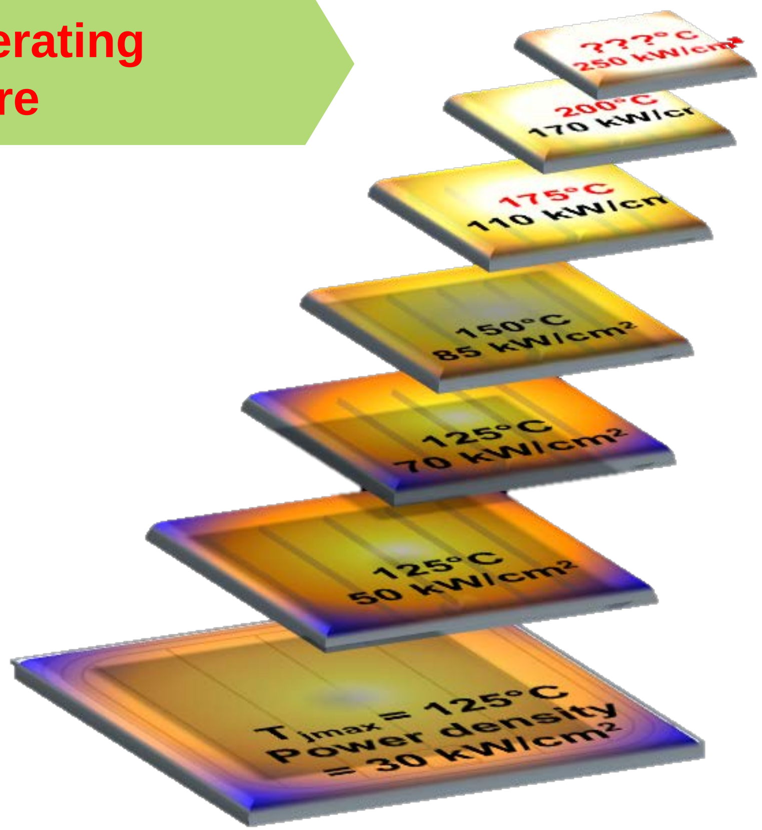
2017 ECTC Special Session, Lake Buena Vista, FL USA May 30, 2017

HDE-HET, Anton Miric

AGENDA

PACKAGING CHALLENGES: POWER MODULE EXAMPLE

Smaller and Thinner Dies › **Increased Power Density** › **Higher Operating Temperature**



Benefit through smaller dies

- Reduction of chip size / cost
- Lower losses / higher efficiency
- Increase of power & current density per chip

Packaging challenges

- Increased power loss per chip area requires materials with **better heat dissipation**
- More power needs better **current carrying capability** of packaging materials
- Increased operating temperatures and **reliability** challenges

Source: Innovative Material Packaging Solutions for superior Power Electronics Devices, EDPC Conference Nov. 2016, Nürnberg, A. Miric, Dr. Frank Osterwald, P. Dietrich, A.S. Klein, A. Hinrich

AGENDA

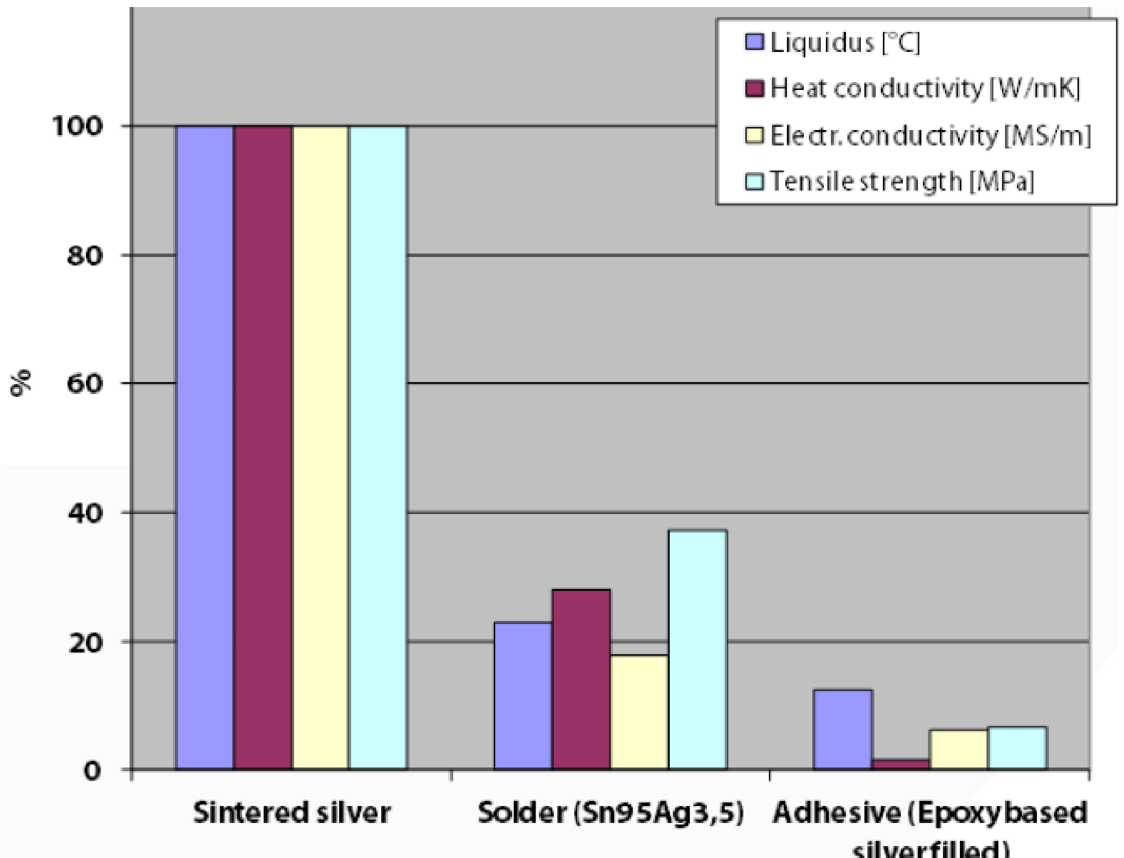
HOMOLOGOUS TEMPERATURE OF SnAg (SnAgCu) vs. SnCu IMP and Ag

› **High operating temperature / reliability driven change**

Material		Unit	SnAg3.5 / SnSb5	SnCu intermetallic phases	Ag
Melting Temperature		°C	221 / 235-240	415	961
Homologous temperature at operating temperature	125 °C	%	81% / 78%	58%	32%
	150 °C	%	86% / 83%	61%	34%
	200 °C	%	96% / 93%	69%	38%
	250 °C	%	106% / 103%	76%	42%

Source: “Requirements for advanced Power Electronics – Status of the ProPOWER Project”,.A. Miric, APE Paris 2013

PERFORMANCE OF SINTER PASTE VS. SOLDER AND ADHESIVE



Source: Ch. Mertens

Material properties	SnAg3.5 Solder	mAgic Paste ASP 295-Series Non-Pressure	mAgic Paste ASP 016/043/338 Pressure Assisted
Electrical resistivity [mΩ·cm]	0.01 – 0.03	≤ 0.012	≤ 0.008
Thermal conductivity [W/m·K]	20 - 50	> 100	> 200
CTE [ppm/K] (below/above T_g)	25 - 30	19	19
E-Modulus @ 25°C [GPa]	~ 30	~ 25	~ 50
Shear strength [N/mm²]	~ 40	≥ 10	≥ 20
Process temperature [°C]	230 – 260	≥ 200	≥ 230
Residue free	No	Yes	Yes

Advantages of sinter paste:

- Operation temperature at least 200°C
- High reliability
- Excellent electrical and thermal conductivity
- No liquid phase at joining process
- High mechanical strength
- Lead-free technology
- Residue free – no flux

Source: Innovative Material Packaging Solutions for superior Power Electronics Devices, EDPC Conference Nov. 2016, Nürnberg, A. Miric, Dr. Frank Osterwald, P. Dietrich, A.S. Klein, A. Hinrich, Own compilation

SINTERING DIES ON Si_3N_4 AMCs WITH DIFFERENT FINISHES (TOSHIBA-MATERIALS),

Paste Application – DEK Horizon IX03
Single card edge printing
Stencil thickness: 75 µm
Printing speed: 10 mm/s
Squeezee pressure: 1 kg

→

Pre Drying of Printed Paste – Binder Oven
Binder Conventional Oven
Temperature: 120 °C
Drying time: 20 min
Atmosphere: N_2 (50 ppm O_2)

→

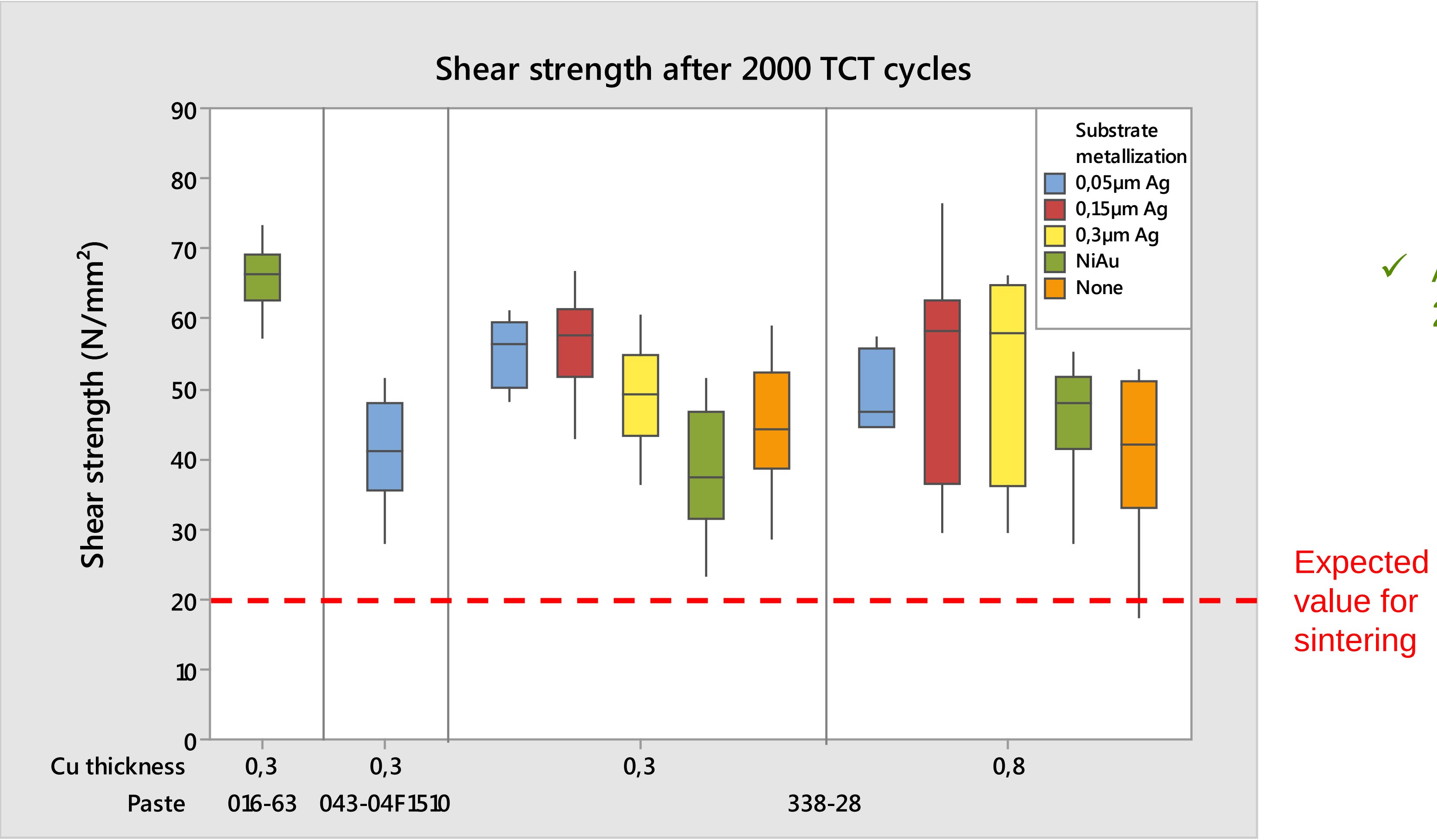
Hot Die Placement – Tresky
Tresky pick and place Equipment
Placement temperature: 130 °C
Placement pressure: 400 g
Placement time: 2000 ms

→

Pressure Sintering – Boschman Sinterstar
Protective Foil PFA Foil
Pressure: 10 MPa
Temperature: 230 °C
Time: 3 min
Sinter under air atmosphere

SHEAR TEST AFTER 2000 TCT CYCLES (-40°C/+150°C)

Ag BSM dummy die 4x4mm²



✓ A slight increase in shear strength after 2000 TCT cycles

Ag BSM dummy die 10x10mm²

No delamination was observed

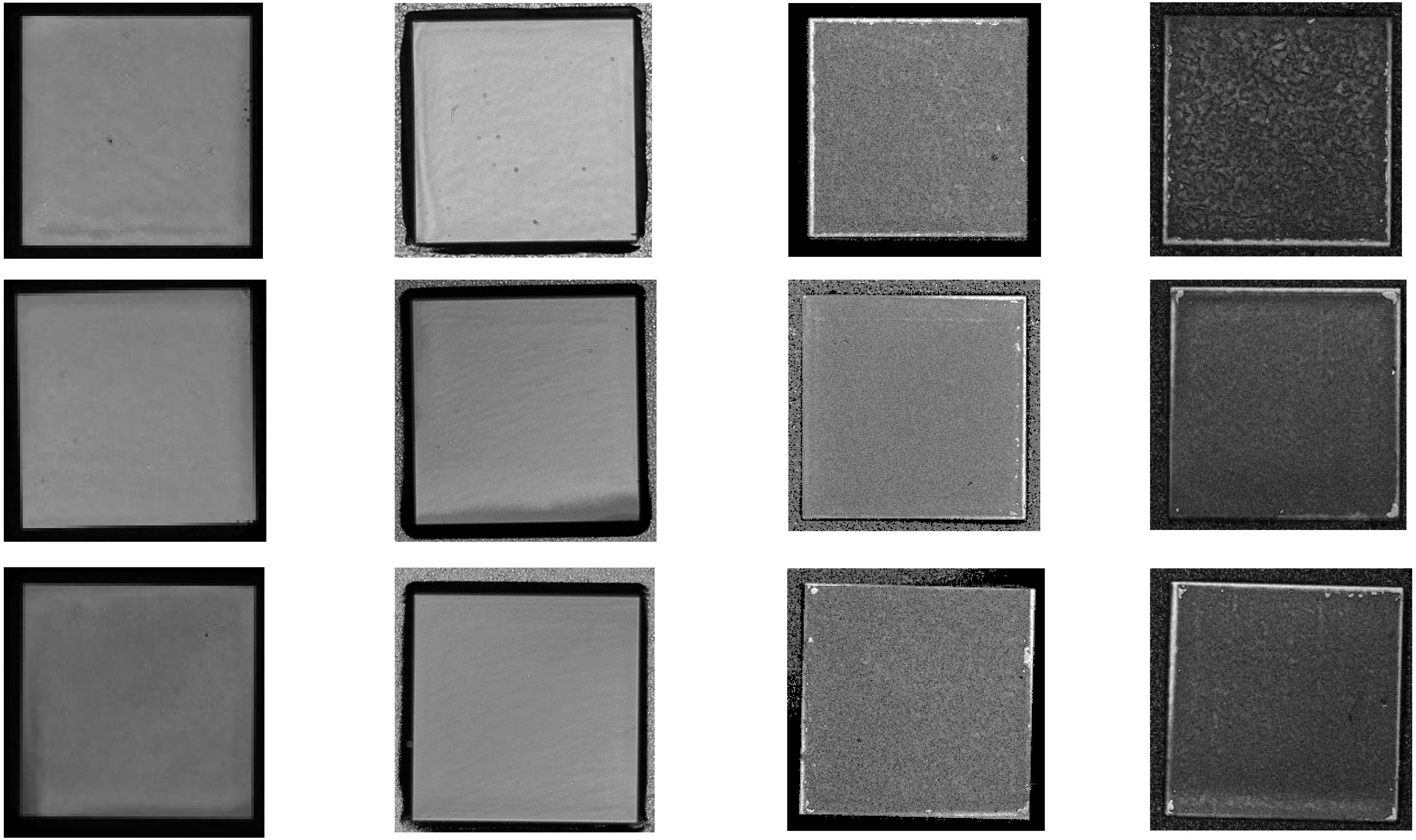
Void under the die < 1%

Initial | 250 cycles | 1000 cycles | 2000 cycles

LTS 338-28P2
0.3µm Ag 0.3mm Cu

LTS 338-28P2
NiAu 0.8mm Cu

LTS 338-28P2
0.8mm Cu



HDE-HET, 2017 ECTC Special Session, Lake Buena Vista, FL USA May 30, 2017

NEW DEVELOPMENTS OF SINTER MATERIALS – BENDING TEST

Sintering on Cu surfaces: dummy die (ISIT 10x10 mm) is attached with pressure sintering to Si_3N_4 AMC (Toshiba-Materials), AMC is bent in special equipment and evaluated for delamination

Initital	After 2,000 TC -40/+150°C

high bending strength

LTS 338-28P2
0.15µm Ag 0.3mm Cu

LTS 338-28P2
0.3µm Ag 0.3mm Cu

LTS 043-04F1510
0.05µm Ag 0.3mm Cu

high bending strength

LTS 338-28P2
0.15µm Ag 0.3mm Cu

LTS 043-04F1510
0.05µm Ag 0.3mm Cu

Heraeus

AGENDA

1 | INTRODUCTION

2 | DIE ATTACH MATERIALS

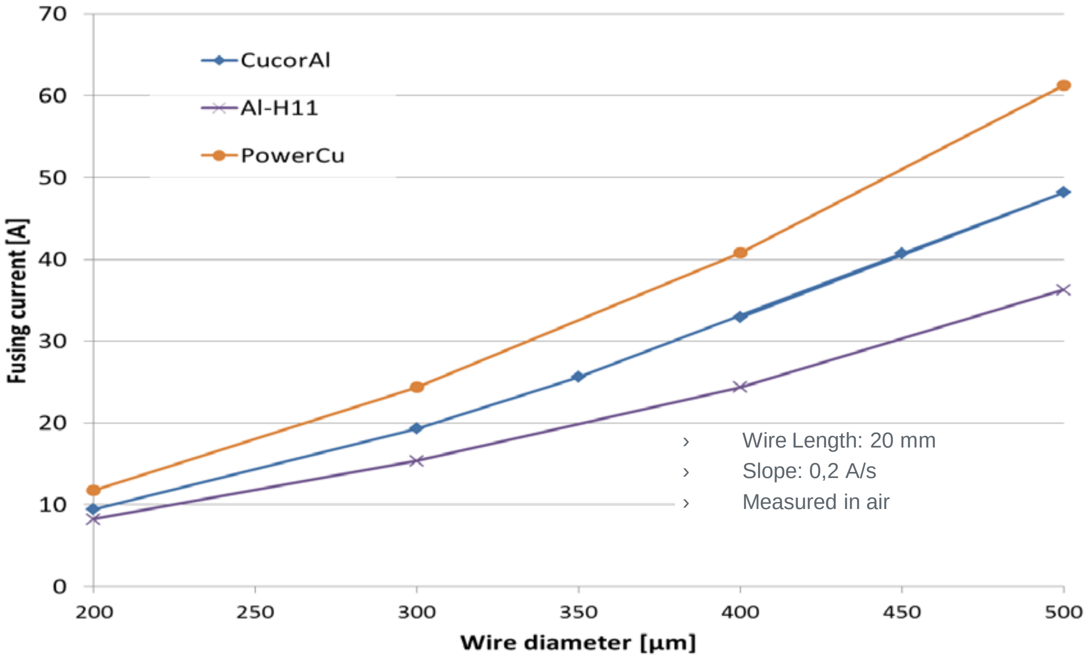
3 | DIE TOP CONNECTION

4 | SUMMARY AND OUTLOOK

Heraeus

PROPERTIES OF BULK Al AND Cu, INFLUENCE ON FUSING CURRENT, CURRENT CAPABILITY AND RELIABILITY

	Unit	Al	Cu
Thermal Conductivity	W / (m * K)	237	401
Electrical Conductivity	A / (V * m)	$37.7 * 10^6$	$59.1 * 10^6$
Tensile Strength	MPa	40 – 50	200 – 230
E-Modulus	GPa	70	100…130
Vickers Hardness	MPa	167	369
CTE	ppm / K	23	17
Melting Point	℃	660.3	1084.6



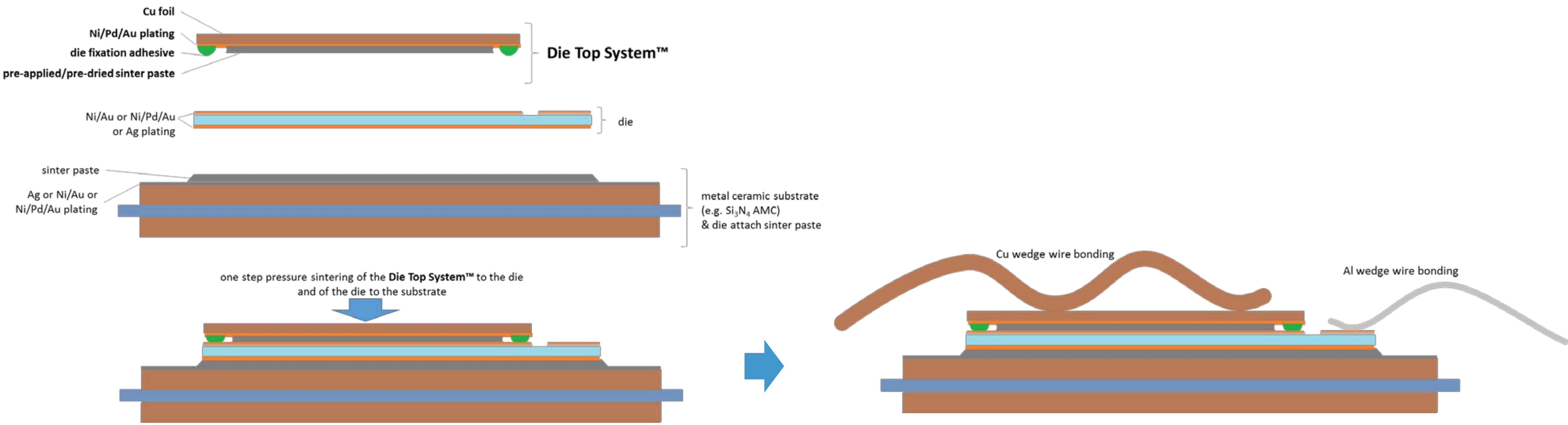
	State of the Art	Die Top System Solution
Bonding wire size	Al 400 µm	Cu 400 µm
Current capability	19 A	32.5 A
Die connection	Al thick wire and solder die attach	Cu thick wire and sintering die attach
Module lifetime	standard	>10 x standard
Max. $Tj_{continuous}$	150 °C	200 °C

DIE TOP SYSTEM WITH PRE-APPLIED SINTER PASTE AND DIE FIXATION

Die Top System is a material system, which consists of:

1. **Cu foil** with functional surfaces optimized for sintering and bonding
2. **pre-applied** and pre-dried **sinter paste**
3. **die fixation adhesive**

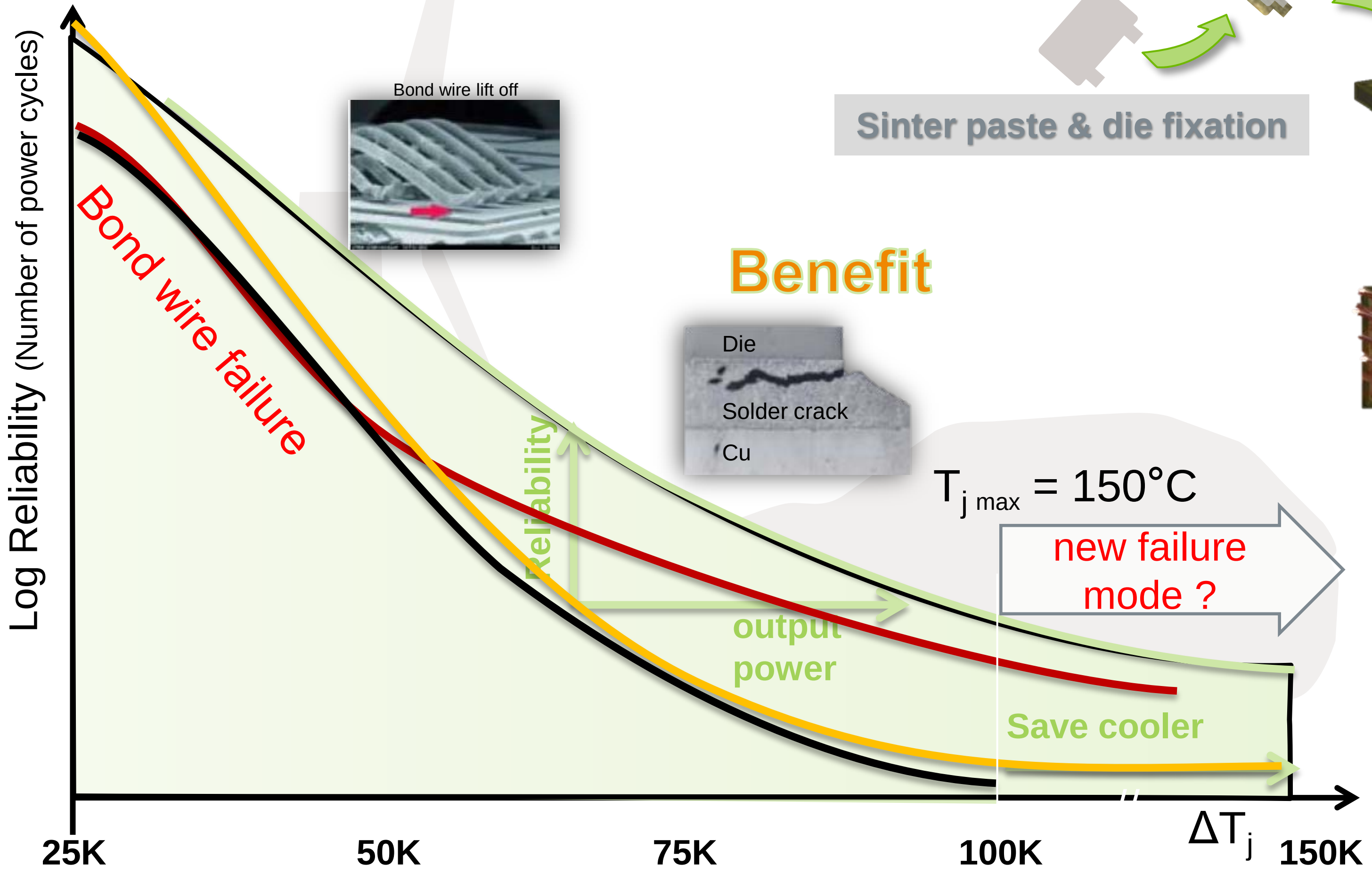
It can be handled like a single components using ordinary production equipment.

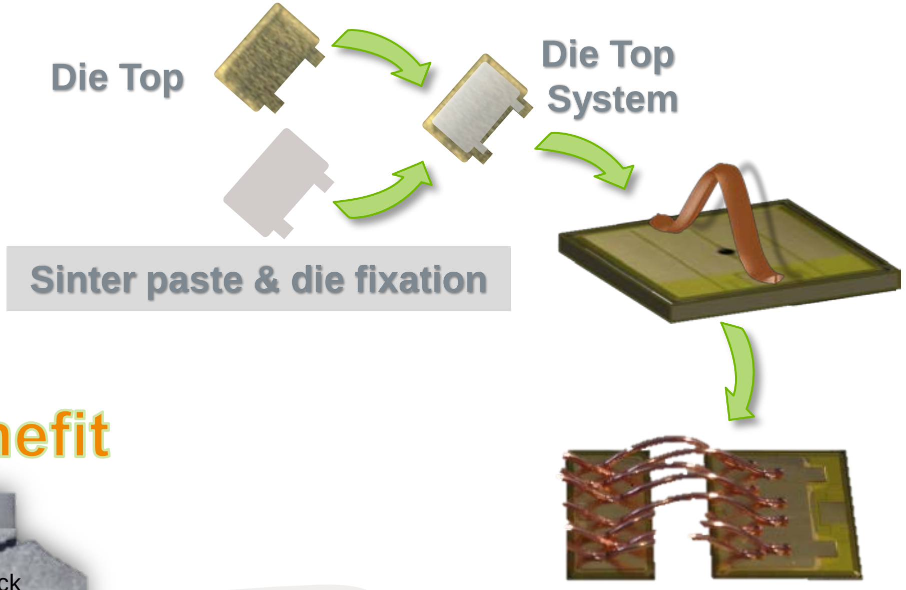


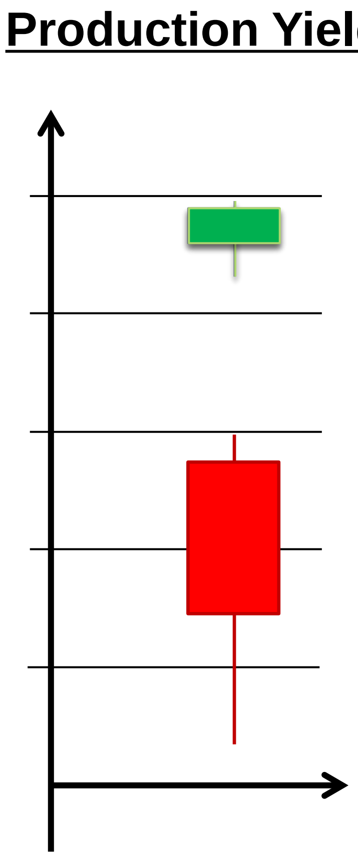
Replace solder by sinter: **No Die attach failure**

\+ Replace Al by Cu wire**: No Bond wire lift off**

\+ DTS: **Yield OK**



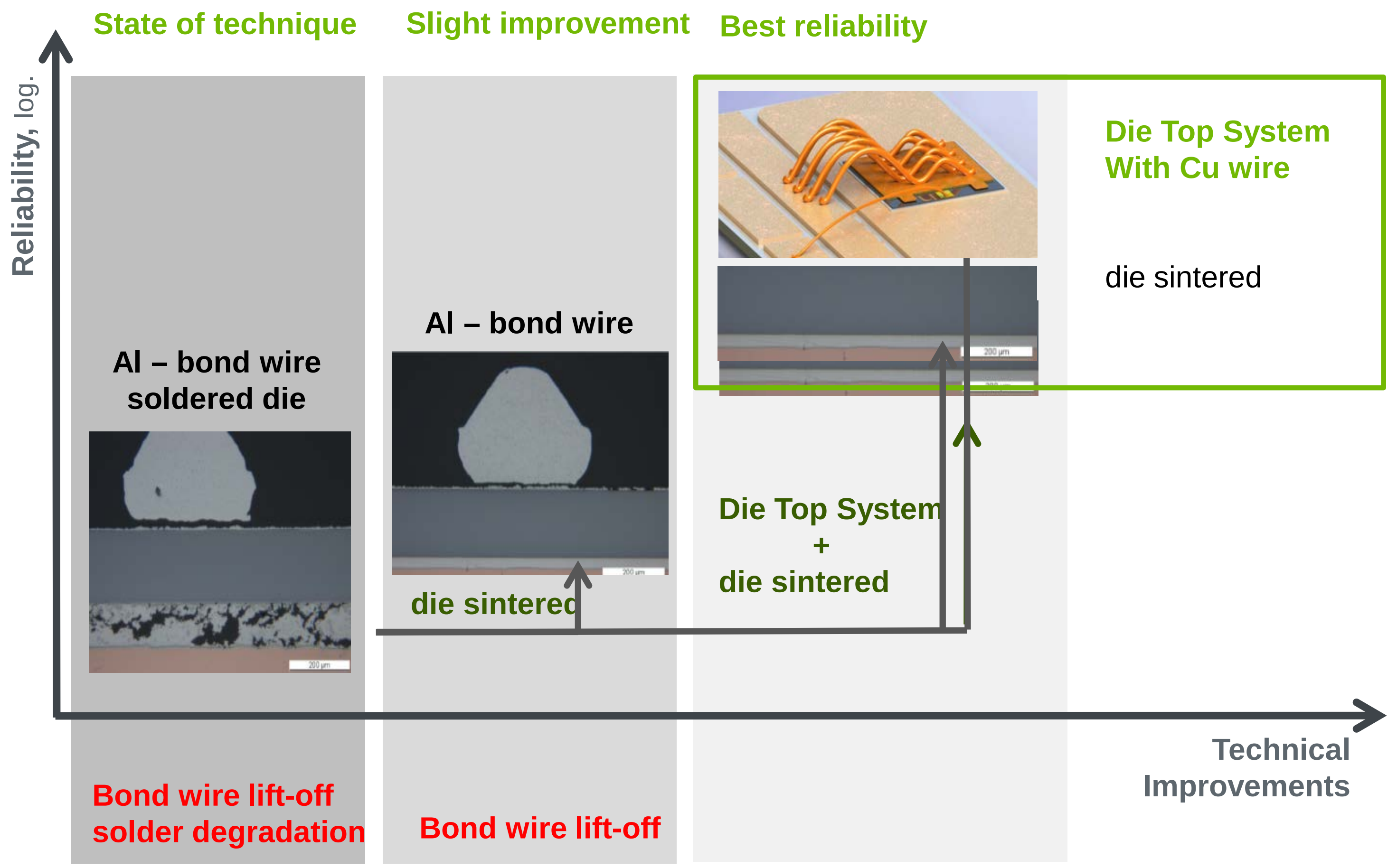




Source: Innovative Material Packaging Solutions for superior Power Electronics Devices, EDPC Conference Nov. 2016, Nürnberg, A. Miric, Dr. Frank Osterwald, P. Dietrich, A.S. Klein, A. Hinrich

AGENDA

BEST RELIABILITY WITH MATCHED PACKAGING MATERIALS SOLUTION



Material improvement in one single **layer** lead to a **small** contribution - it shifts weakest point to the next joining layer.

A **holistic approach** is needed.

It is necessary to work on **solutions**, which take into account the **whole stack of materials** in the power module **to enable significant reliability and performance improvement.**

Source: Prof. Eisele FH Kiel, Danfoss, own compilation

Heraeus

THANK YOU!

YOUR HERAEUS ELECTRONICS

Enabling you for future devices