Silver Sintering for Power Electronics

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Henkel Excellence is our Passion

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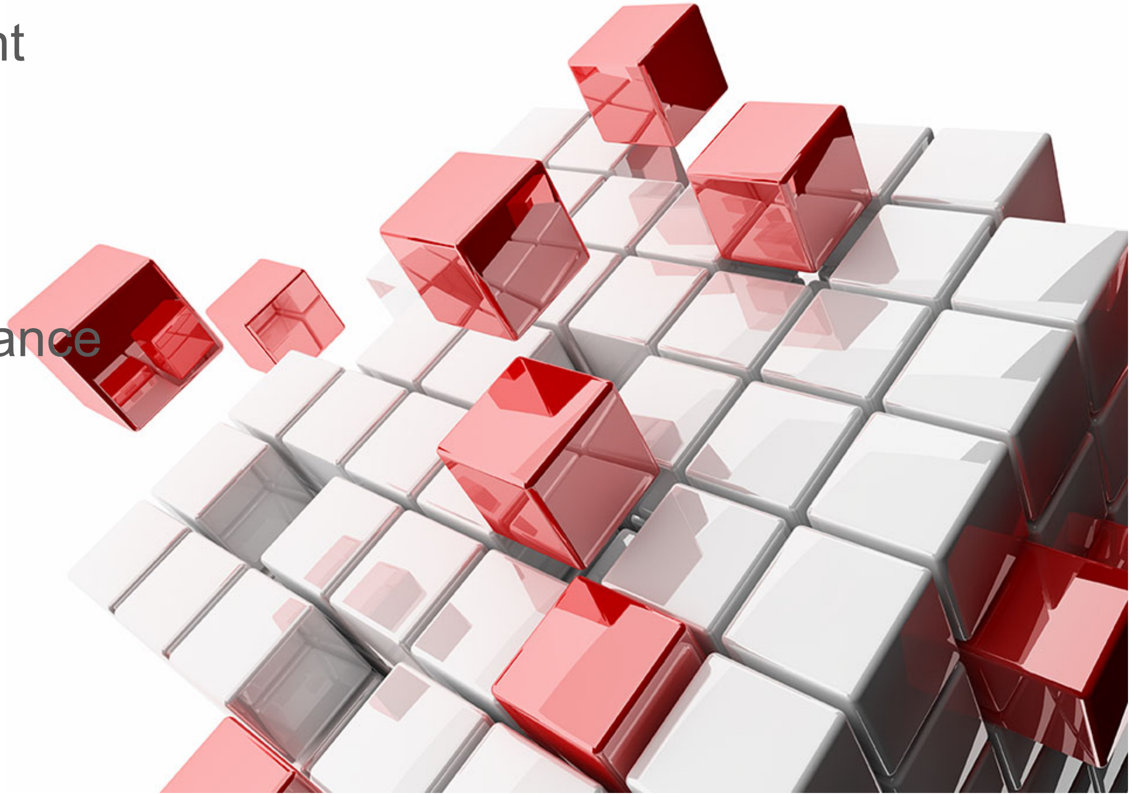
2. Performance of Loctite ABLESTIK SSP2020
3. New product development
    - Low porosity
    - Reduced stress
    - Power cycle performance
4. Conclusions



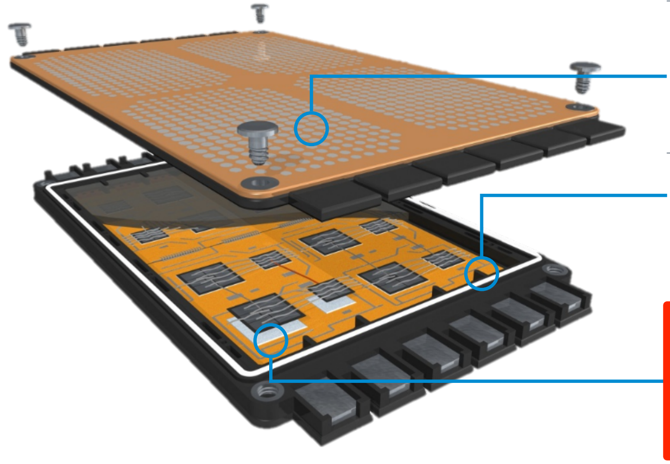
Power Electronics
Material Development Focus

Technology Trends

- Increased Switching Speeds/ Frequency
- Higher Voltage
- Higher Operating Temperature
- Low Power Loss

Customer Needs

- High Reliability
- Low Stress Materials
- Ease of Processing
- Lead-Free / Halogen-Free

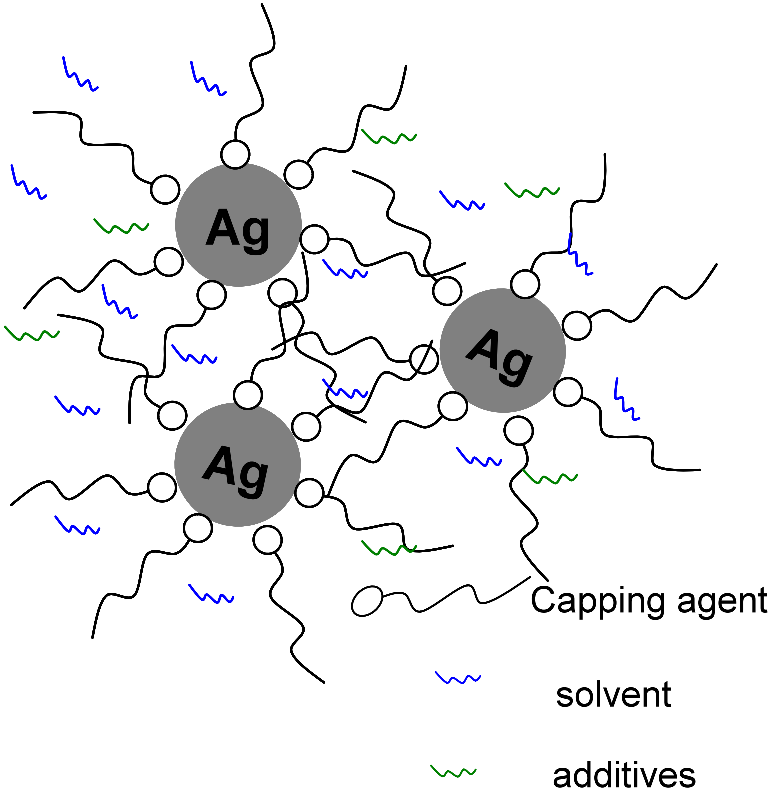


Henkel Solutions

Pre-applied Phase Change Thermal Interface Material	• Replace Thermal Grease • Easier to Process • Higher Reliability
High Temperature Molding Compound	• Replace Silicone Gel Casing and Fasteners • Very High Reliability
Silver Sintering Die Attach	• Replace Solder Paste • Lead Free/Halogen Free • High Reliability

Technical Approach

Ag Sintering formulation



Silver

- Particle size distribution
- Lubricant type/amount
- Tap density
- Surface area
- Loading (> 85% of formulation)

Additives

- Sintering aid or dispersing aid
- Decomposition temperature

Solvent

- Dispersion of Ag
- Evaporation rate/temperature
- Loading (as low as possible)

Industrial Application Process pressure sintering SSP2020

Process Flow

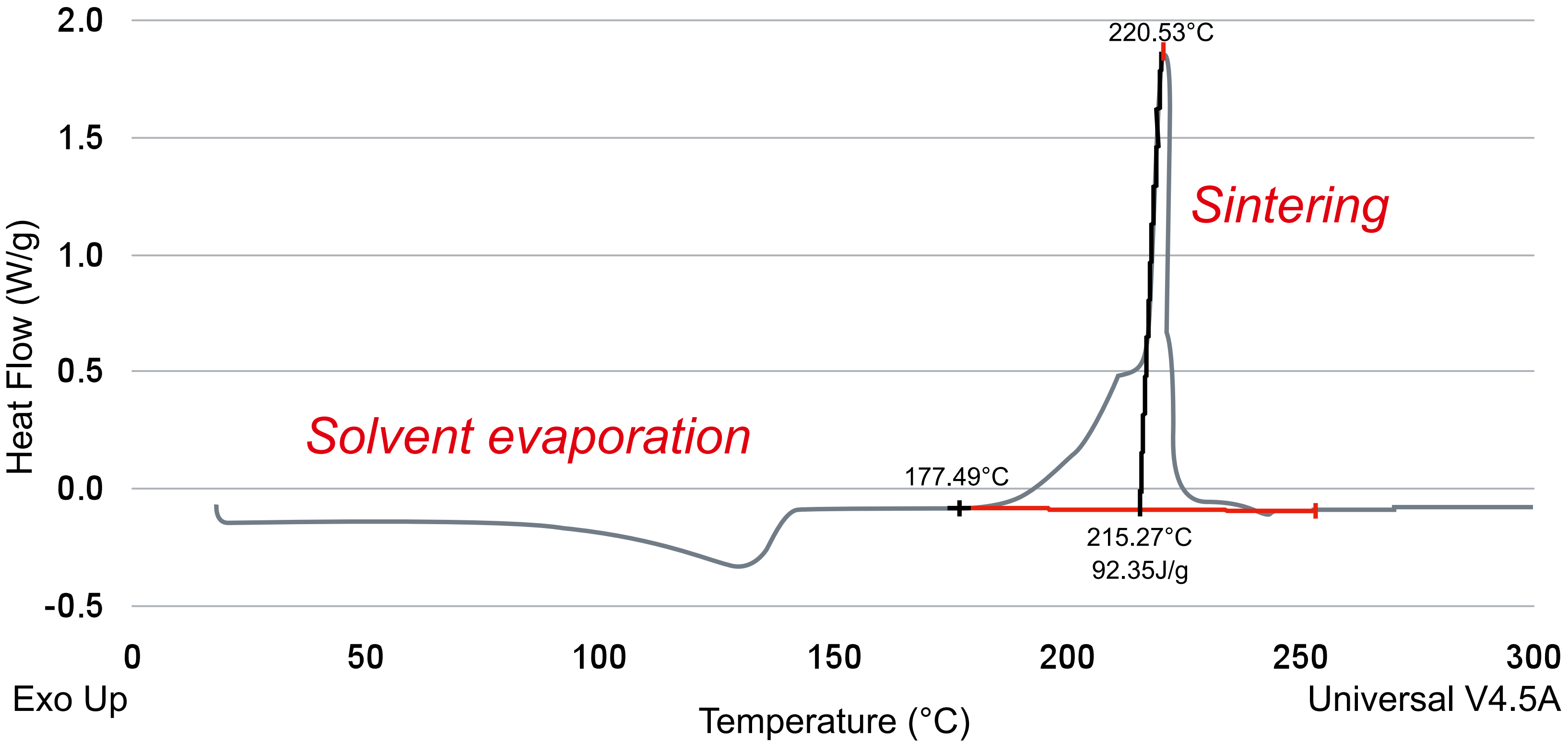
Process	Paste Application	Paste Drying	Die Placement	Paste Sintering
Equipment	Conventional printer	Conventional box oven	Pick & Place	Sinter Press
Key Parameters	Stencil printing: 50-100µm Print speed: 20-100mm/s Squeegee pressure: 3-6 kg	Drying time: 20 min Drying temperature: 120°C Drying in air	Low pressure, short heating to set the die	Sinter pressure: 10MPa Sinter temperature: 250°C Sinter time: 2 min

⊕ strong adhesion, dense sintered layer, proven thermal and electrical conductivity and proven reliability in power cycling

⊖ new equipment required, risk of die crack under high pressure

LOCTITE ABLESTIK SSP2020
DSC study

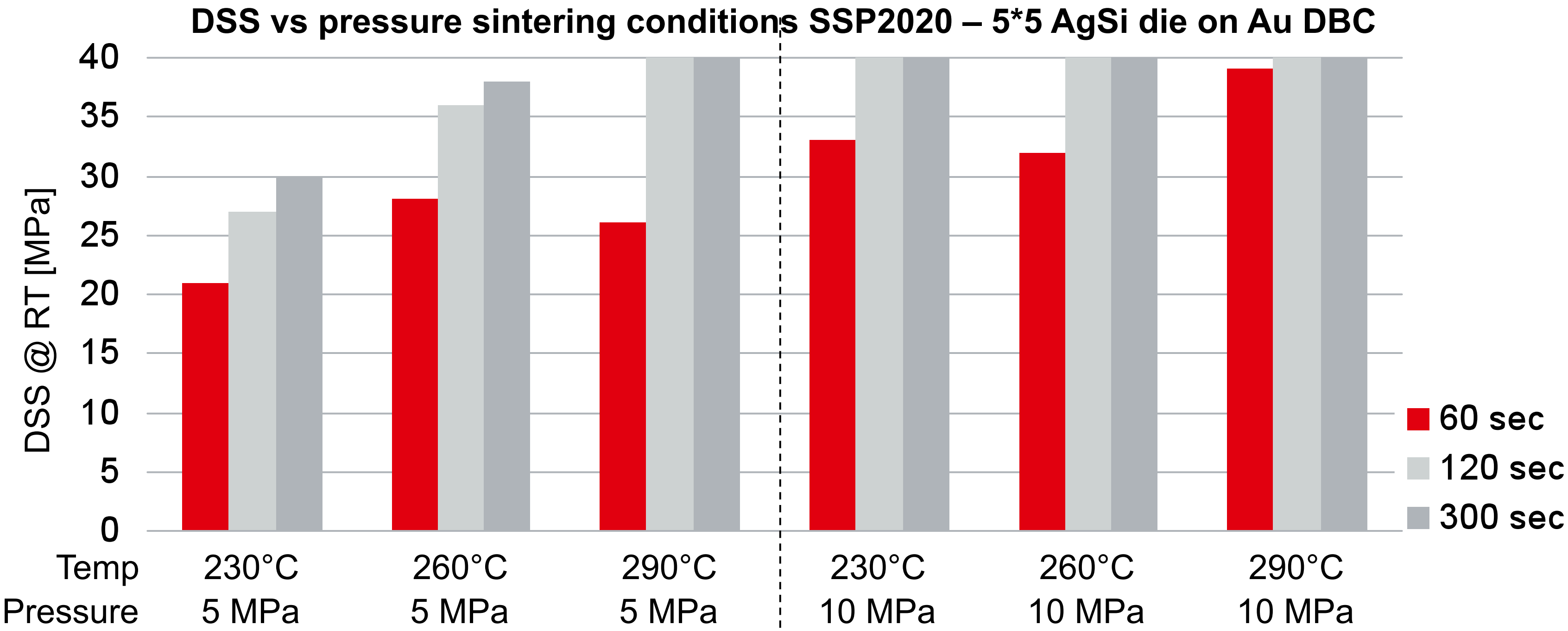
Product	**LOCTITE ABLESTIK SSP2020**: Henkel's commercial Ag sinter material
Test	Dynamic DSC (open Al flat pan) 25°C till 300°C, 10°C/min ramp, 50 ml/min air



Effect of Sinter Conditions on Adhesion Strength

DSS

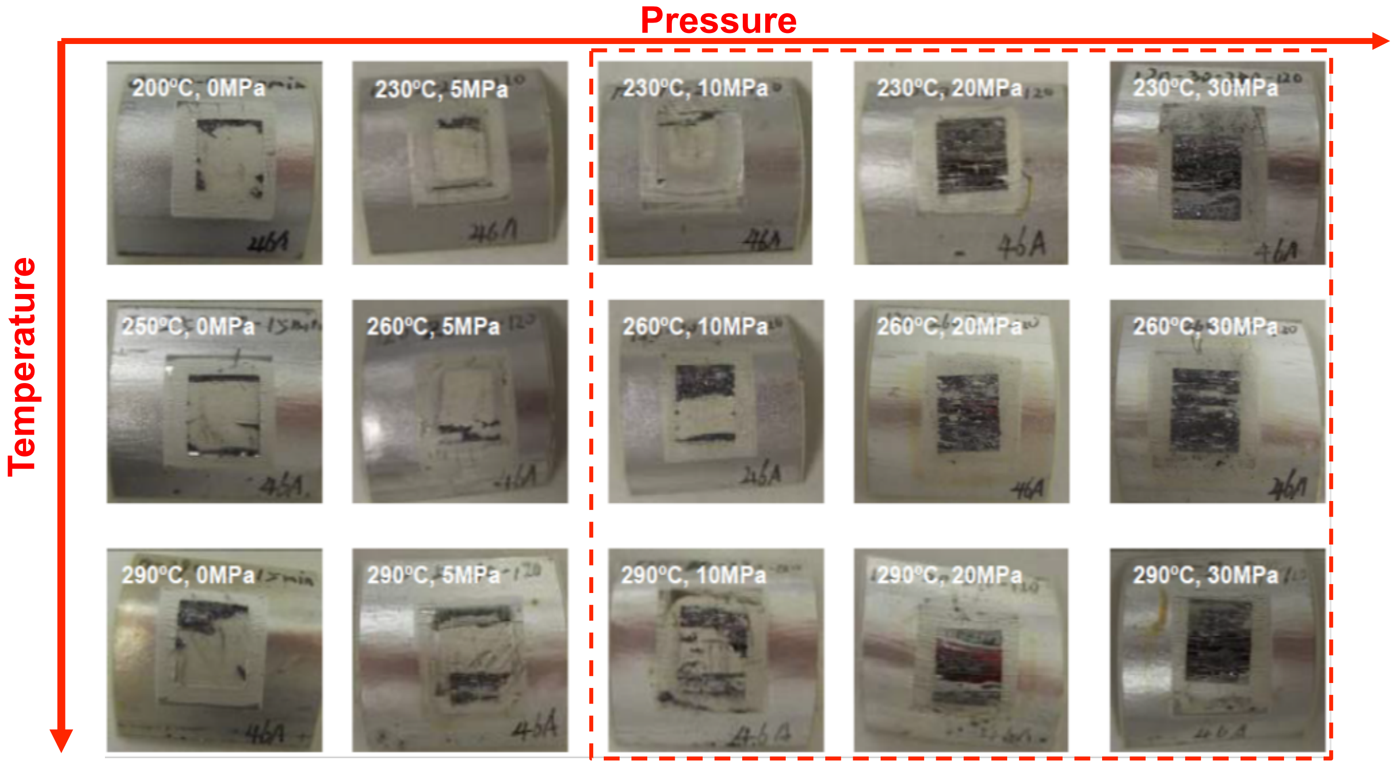
Product	**LOCTITE ABLESTIK SSP2020**
Drying	40 min @ 120°C
Sintering	5-10 MPa, 230-260-290°C, 60-120-300s – 5*5 mm^2 die **on Au DBC**
Measuring	DSS @ RT



Effect of Sinter Conditions on Adhesion strength

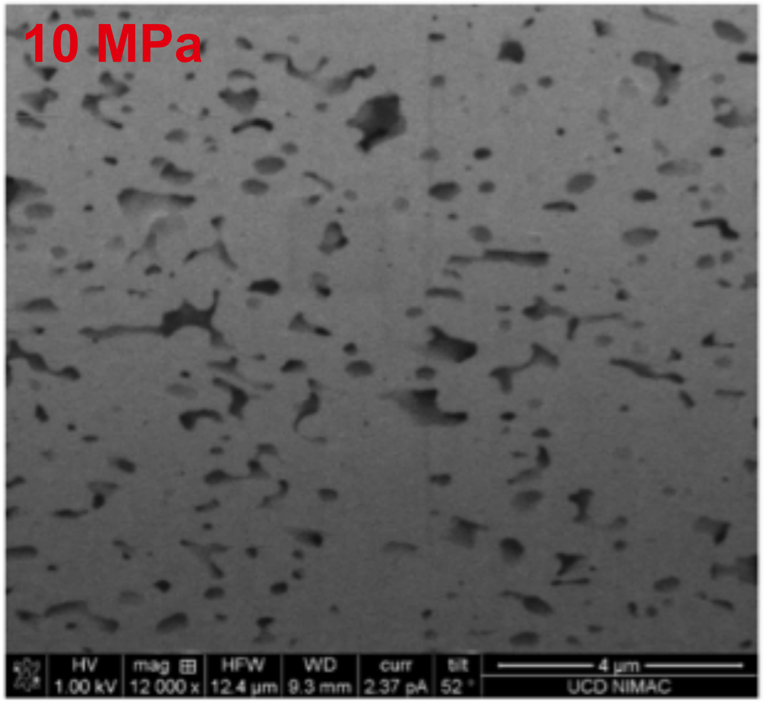
Bend Test

Product	**LOCTITE ABLESTIK SSP2020**
Drying	40 min @ 120°C
Sintering	0-5-10-20-30 MPa, 200-230-250-260-290°C, 120s – 8*8 mm^2 die on **Ag DBC**
Measuring	Mandrel bend testing



Effect of Sinter Pressure on Porosity

Product	**LOCTITE ABLESTIK SSP2020**
Drying	40 min @ 120°C
Sintering	260°C, 90s
Measuring	FIB-SEM analysis



< 12.2% porosity at 10 MPa sintering pressure
< 6.5% porosity at 20 MPa sintering pressure
< 5% porosity at 30 MPa sintering pressure

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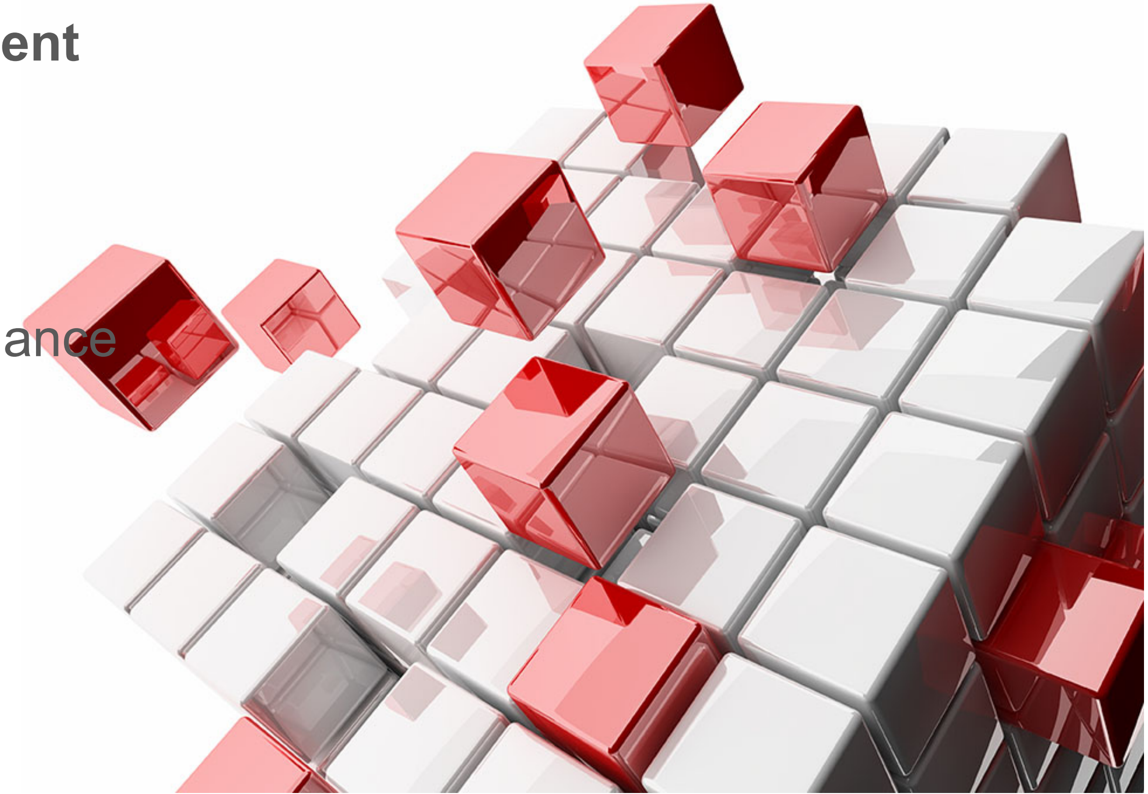
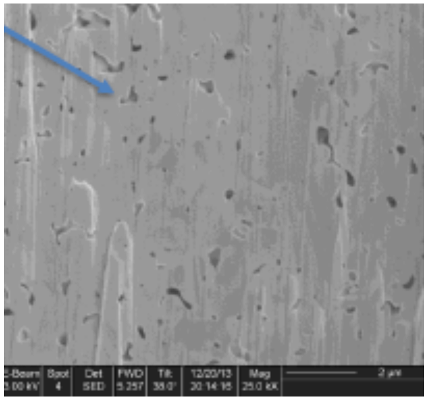
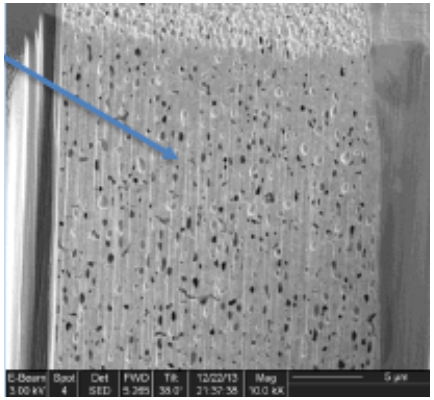


Porosity after pressure assistent sintering

	FIB SEM
EXPERIMENTAL Material	3% 
Loctite Ablestik SSP 2020	15% 

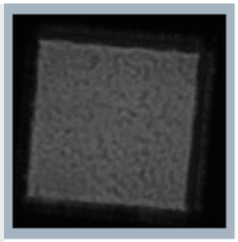
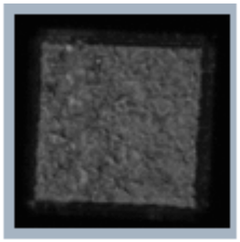
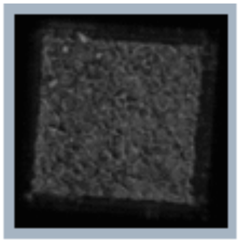
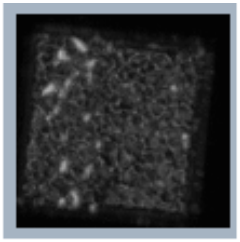
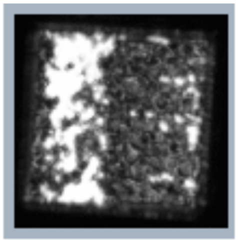
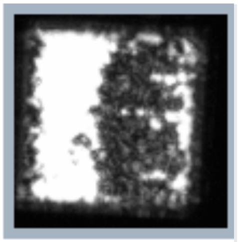
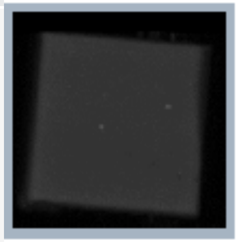
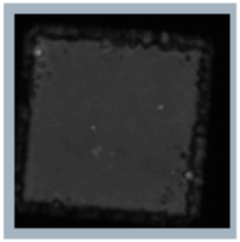
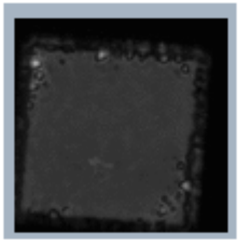
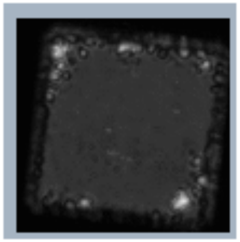
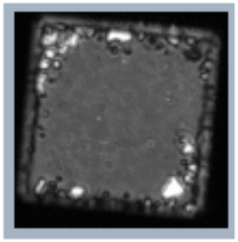
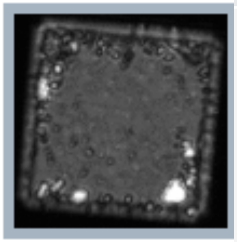
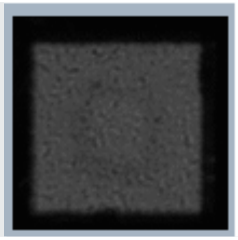
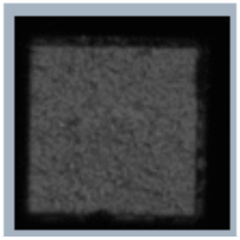
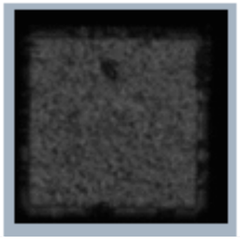
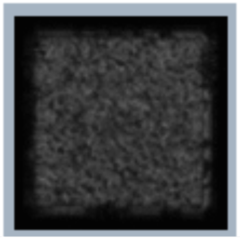
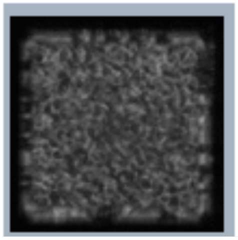
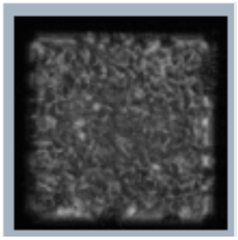
By selecting new silver fillers lower initial porosity numbers can be obtained

Passive thermal cycling

-55/175°C

5*5 mm^2 die on Ag-DBC
Sinter profile : 10 MPa, 5 min 300°C

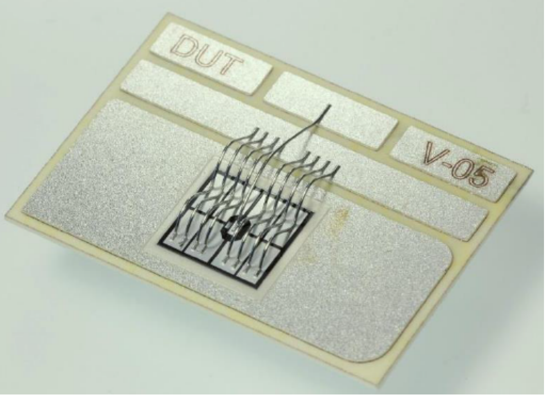
- Experimental material 1 contains new silver filler leading to lower porosity
- Experimental material 2 contains stress reducing raw materials

	Initial	100 cycle	150 cycle	250 cycle	500 cycle	750 cycle
SSP 2020						
EXP 1						
EXP 2						

Stress reduction in the Ag sinter material enables thermal performance

Active power cycling
Materials - assembly

Material	Ag DBC	Run	Number DUTs
SSP2020	20 MPa	1	6
Exp Henkel	20 MPa	1	6
Competitor 1	10 MPa	2	6
SSP2020	10 MPa	2	6
Exp Henkel	0 MPa	1	6
Competitor 2	20 MPa	2	6
solder		1+2	4



DUT = Device under test

Assembly:

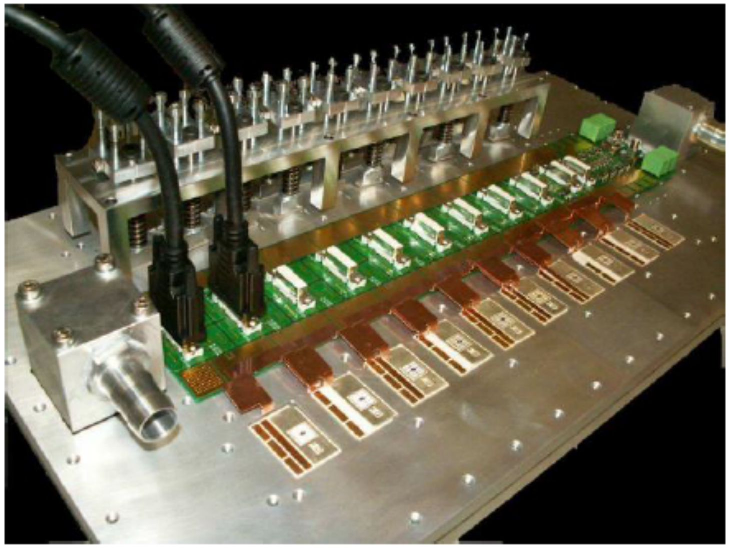
-Die: 10x10mm IGBT3

-Substrate: DBC

-Materials and Processing

- Solder: SAC305, Vacuum oven/N2/Form
- SSP:
  - Pressure: Print > Dry > Die P/P > Pressure sintering (120s at 250°C)
  - Pressure less: Print > Die P/P > Oven sintering (1h at 250°C)
  - Wirebonding: 300µm Al-wire. 8 wires with loop and stich for each die.
  - Quality check before power cycling: SCAM and electrical (blocking voltage 400V)

Active power cycling
Test parameters - goal



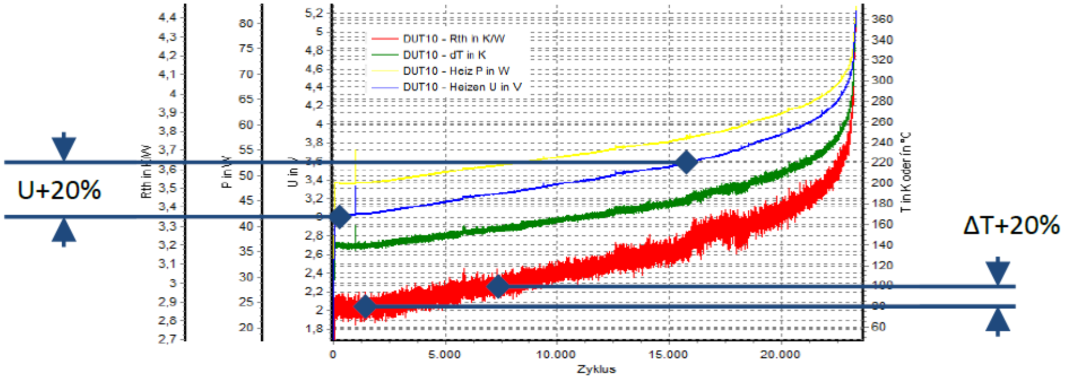
Per run, 20 DUTs are pressed on a cold plate with spring contacts, a thermally conductive foil is placed beneath each DUT

Test parameters:

- Coolant Temperature T_{min} = 40°C
- Load current 50A
- Targeted Temperature swing ΔT = 130K
- Heating voltage drop: 1.3 ~ 1.9V
- Cycling time ts = 30s (15s on /15s off)
  (500 hours for 60,000 cycles)

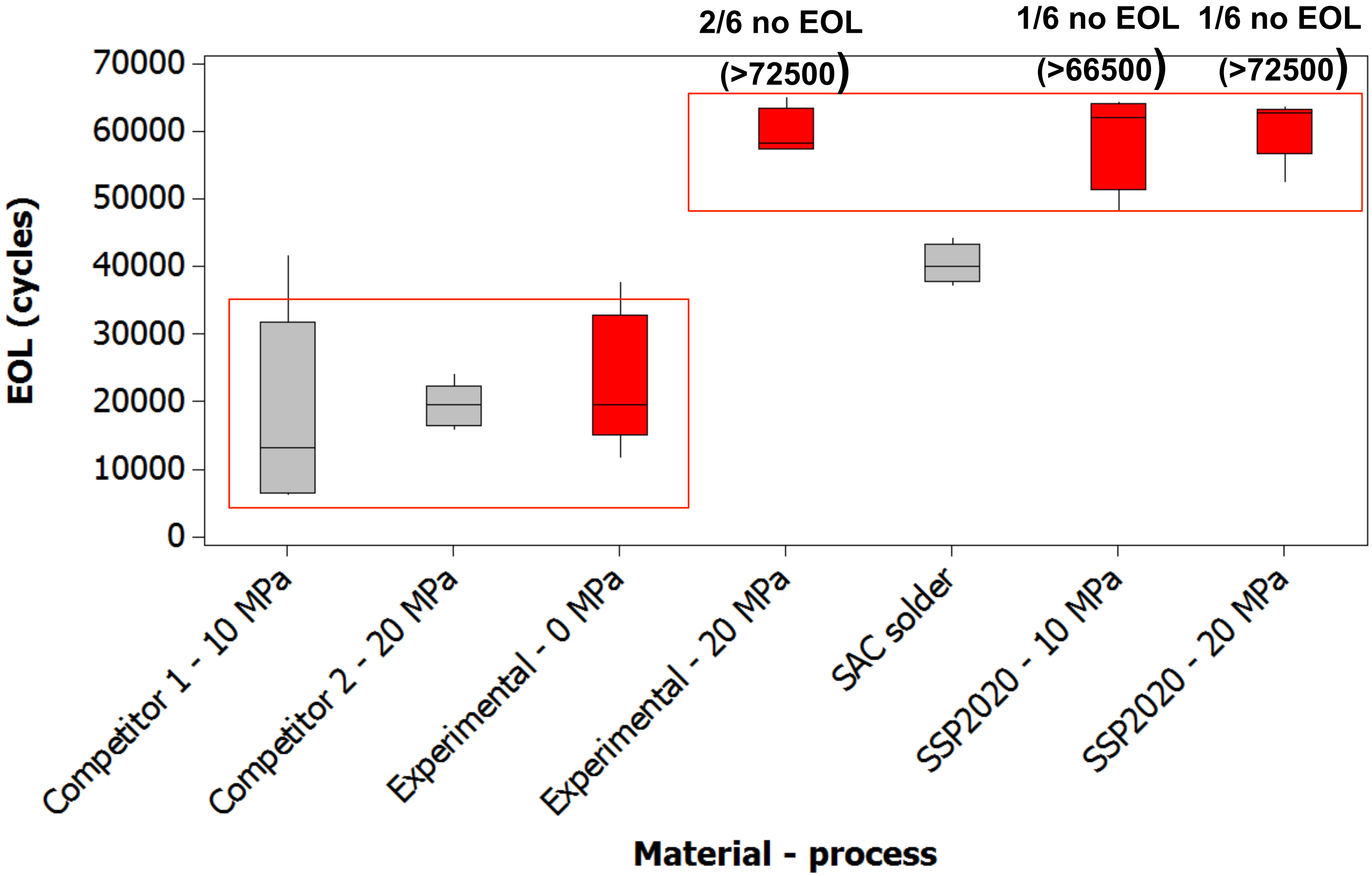
End_of_Life (EOF):

- 20% increase in V
- 20% increase in Rth
- 20% in Temp swing

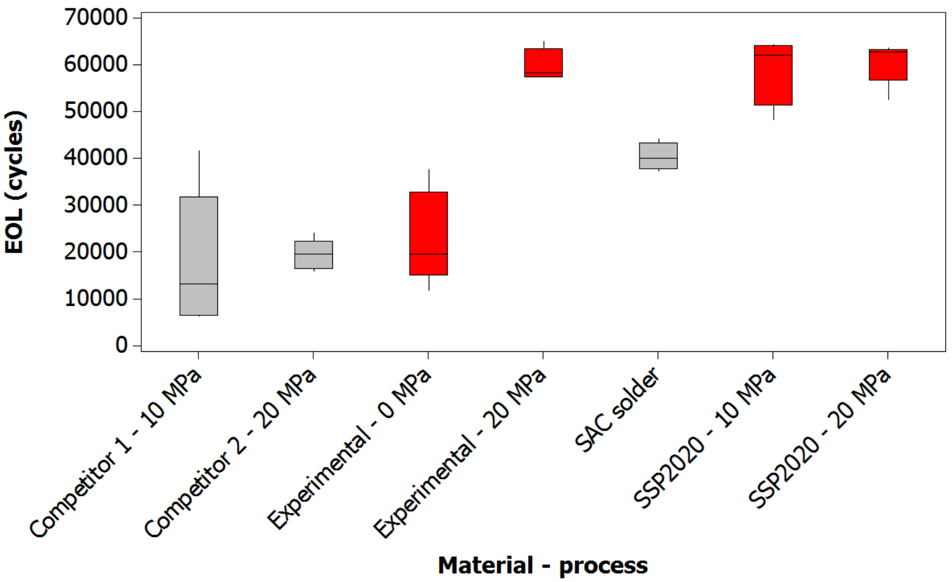


Active power cycling

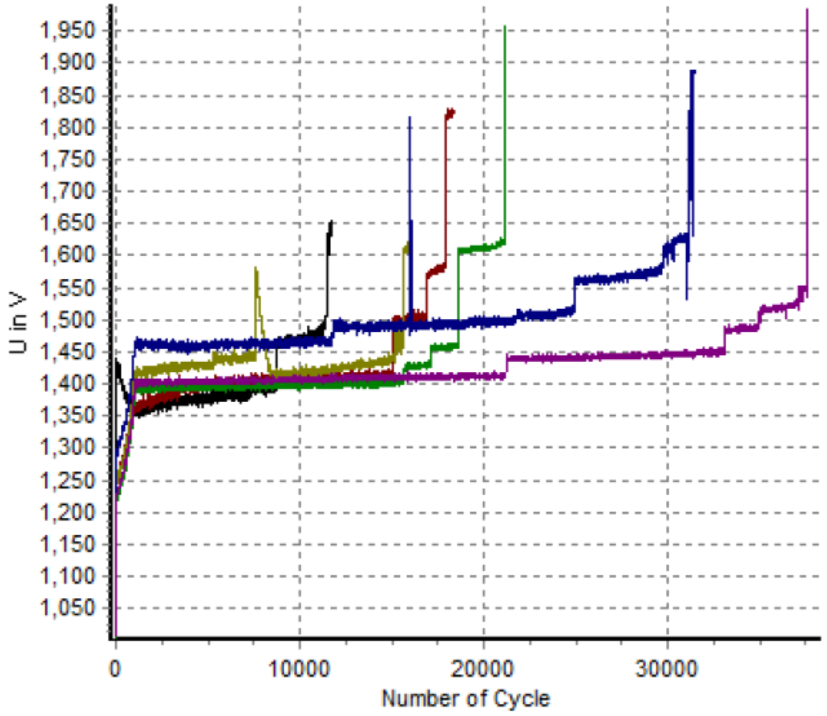
Results



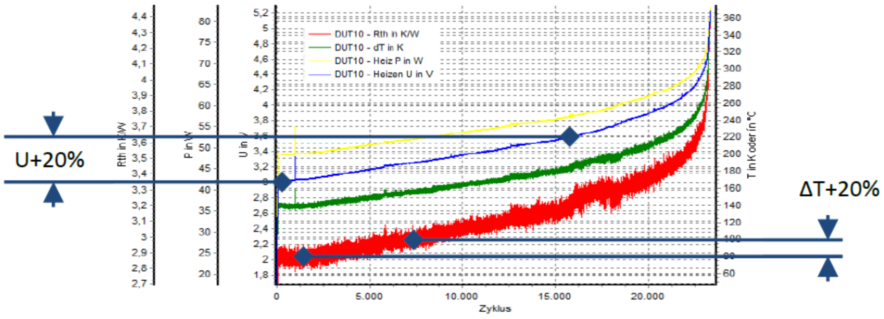
Active power cycling
Results



Failure Mode: Wire Bond Lifting



Step increase of Voltage: indication of wire bond lifting

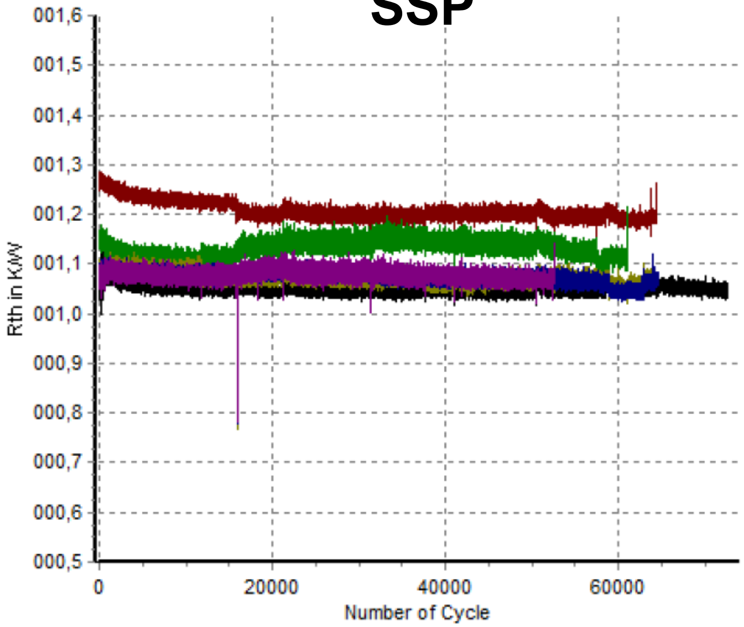


Reference: gradual increase of voltage

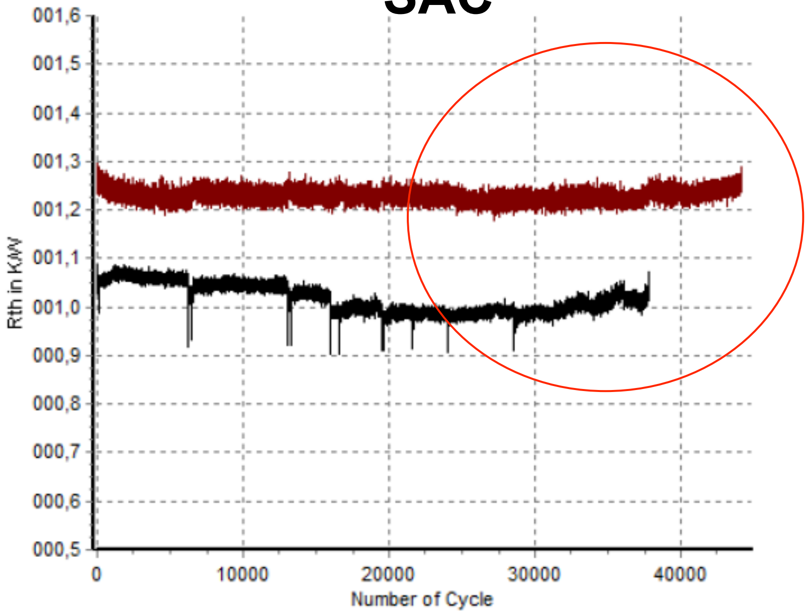
Active power cycling
Results

Silver Sinter vs Solder Paste

- **No indication of material degradation**
  - **No bondline structure change**
  - **Stable thermal resistance**



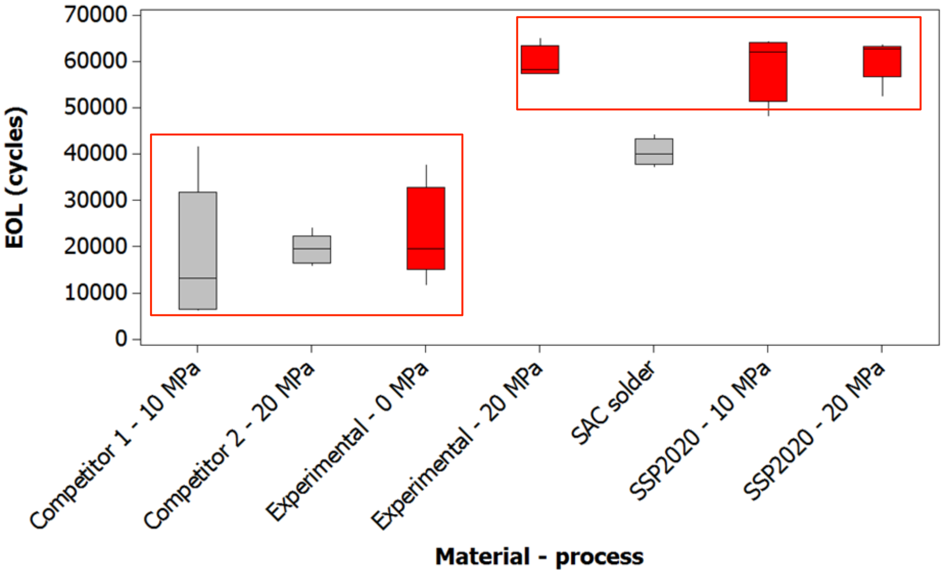
SSP



SAC

Active power cycling

Results



Material Deterioration

Device EOL
Voltage, Temp Swing, Rth

?

Other CMPT lifetime
Wire Bond
Substrate
Power Die

Possible material properties (heat dissipation, stress reduction) enables longer WB lifetime.

Active power cycling
Results

- Cause of failure for all DUTs: aluminium bond wire lift off
- Degradation of SAC solder observed (increase in R_{th})
- No degradation of sintered interconnections observed based on stable R_{th} value over full cycling range for all groups
- Follow up check: porosity in power cycle builds
- In order to look at full potential of sinter material bond and not have bond wires as lifetime limiting factor:
  - Sinter bond wires (good process not established)
  - Change wire bonds (Al/Cu clad, Cu wires: requires top side metallisation change of die)

Conclusions

- Henkel Ag sinter pastes have excellent adhesion performance (die shear strength, bending strength).
- Henkel Ag sinter pastes have good performance in active power cycling. Full realize of sintering mateiral properties need more robust wire bond solution.
- Current sinter pastes have improved performance over SAC solder which is used as a standard in power electronic module assembly.
- It is still not fully clear which paste properties are most important to lead to good active power cycle performance.
  - Certain minimum adhesion is needed to survive wire bond process
  - Low porosity will likely help to increase life time
- New Henkel developments are focused on lower sinter temperature and improved stress reduction to overcome failures due to CTE mismatches in the power module.

Thank you!

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