# Power module technology with extended reliability for hybrid electric vehicle applications

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# Power module technology with extended reliability for hybrid electric vehicle applications

Some results of the joint project „**E**lectric Components **f**or **A**ctive Gears“ (EfA), with financial support by German government (BMWi)


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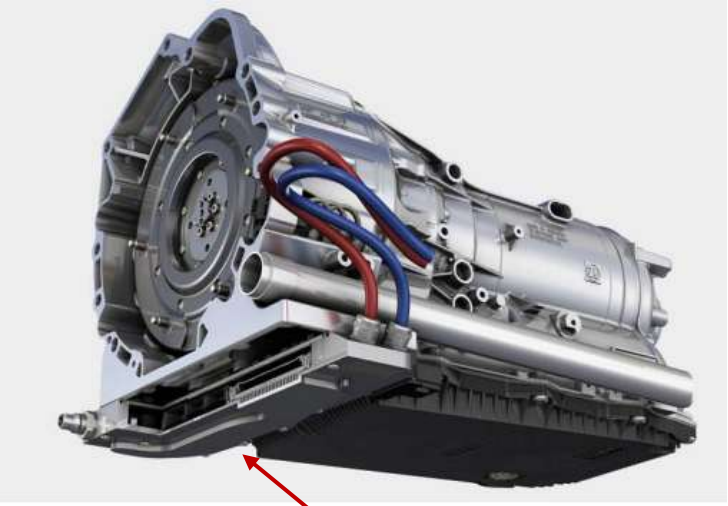
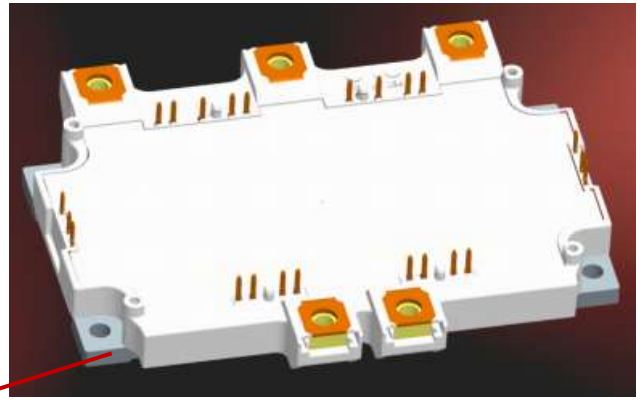
für Wirtschaft
und Technologie

**FKZ 19U6006A-F, 19U8006G**

[Her12]

# EfA: Power electronics cooled by cooling circuit of the combustion engine





Aim:
Use combustion engine coolant (105°C, worst case 125°C)

$T_{jmax}$ 200°C, sufficient power cycling capability

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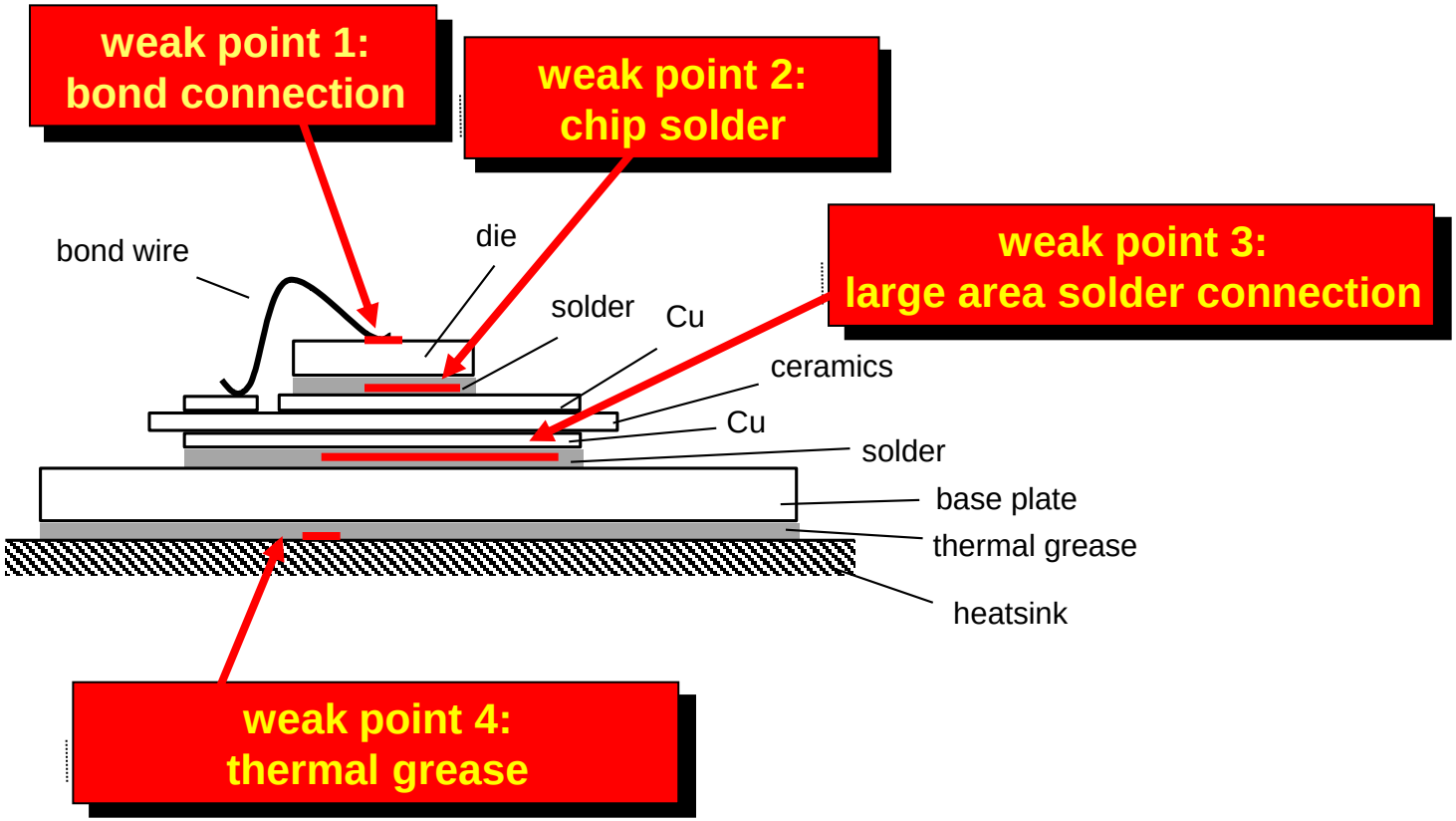
# Weak points in packaging technologies to be adressed



EfA: **E**lectric Components **f**or **A**ctive Gears

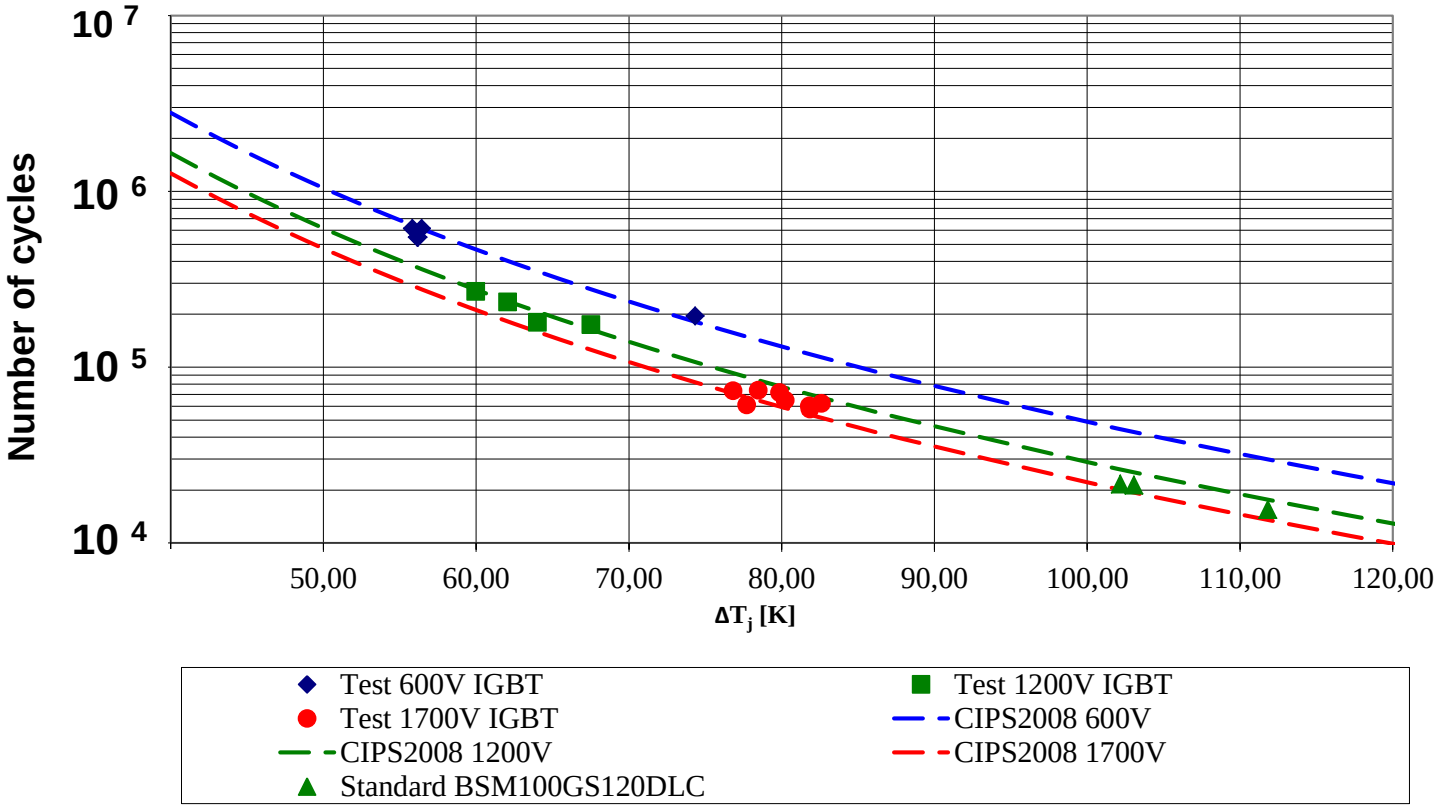
- reference standard modules
- improved bond interconnections (doped bond wires)
- different chip thickness

  V = 600V (chip thickness 70µm)
  1200V (chip thickness 120µm)
  1700V (chip thickness 180µm)

Comparison with former work (CIPS 2008)

$$N_f = K \cdot \Delta T_J^{\beta_1} \cdot e^{\left(\frac{\beta_2}{T_J+273}\right)} \cdot t_{on}^{\beta_3} \cdot I^{\beta_4} \cdot V^{\beta_5} \cdot D^{\beta_6}$$ ($T_J = T_{low}$ in °C)

## EfA results #1




End-of-Life: $R_{th}$-increase.
Root cause: fatigue of chip solder

Improved bond wires alone: no increase of reliability at these conditions.

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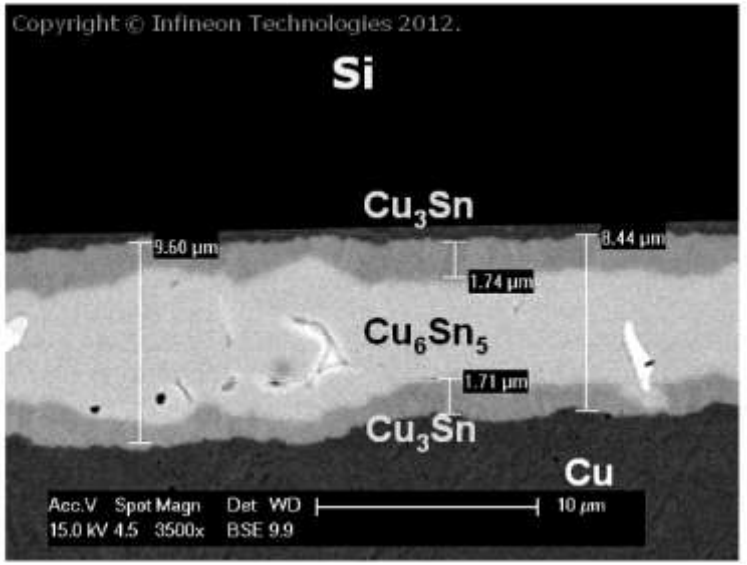
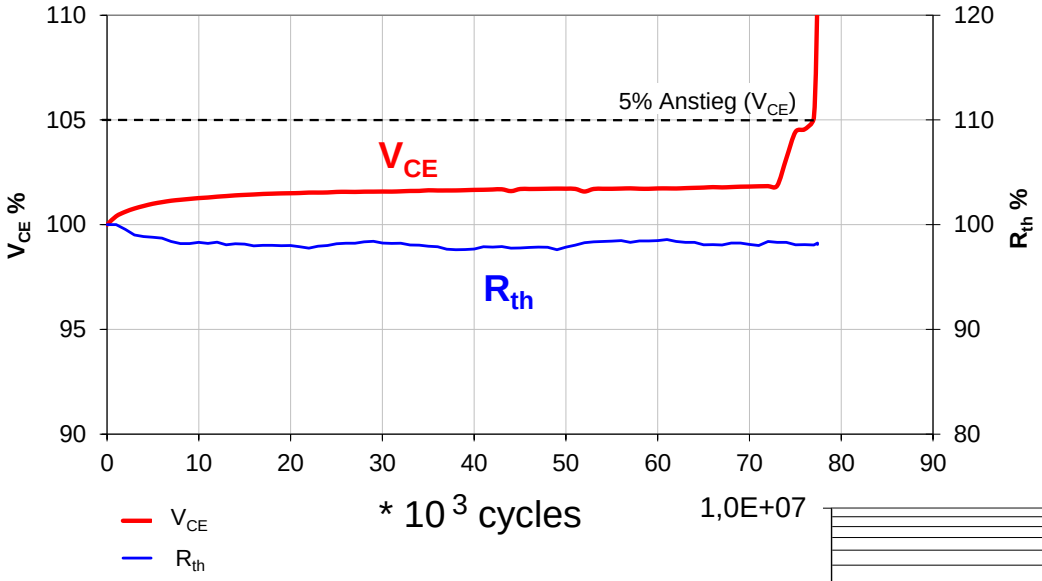
# EfA results #2

- Diffusion soldering
- all other production steps like standard modules




Test conditions:
$T_{jmin}$ = 75°C; $T_{jmax}$ = 175..187°C;
$t_{on}$ = 1..4sec; $t_{off}$ = 3..6sec;
$I_{Load}$ per bond foot = 9.4..12.5A

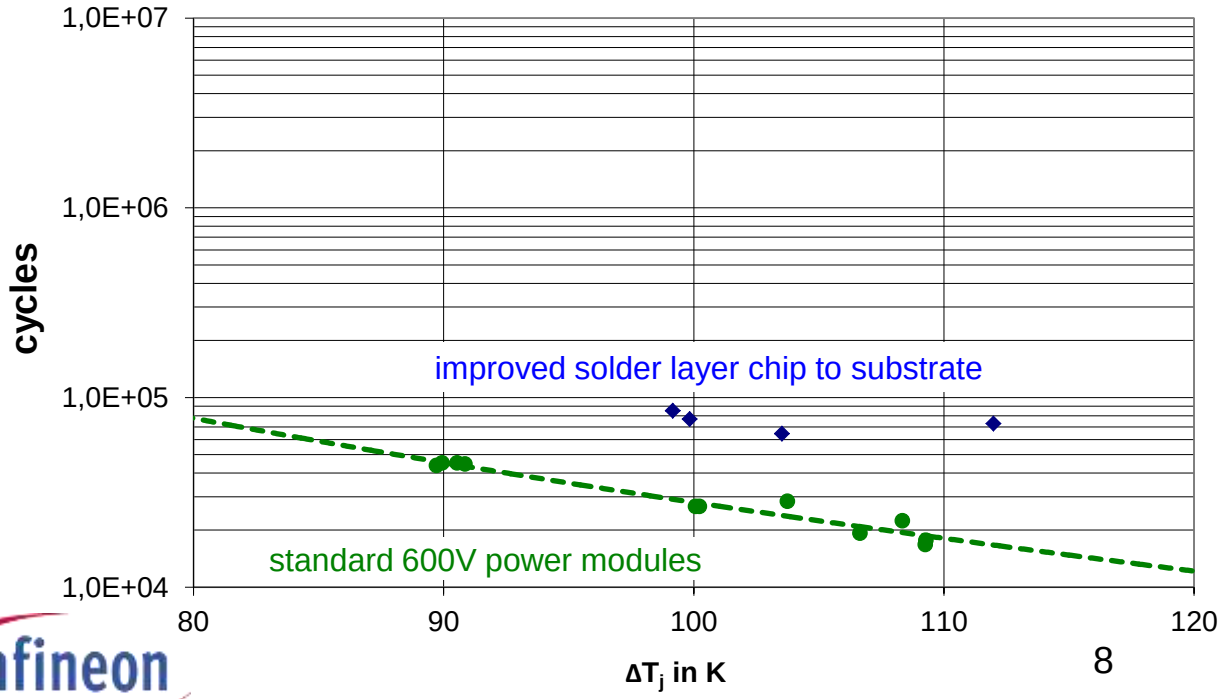
# EfA results #2




All failures: Bond-Wire Lift-off

Diffusion soldering leads to a significant improvement (factor 3)

all tests with
$T_{jmin}$ 75°C

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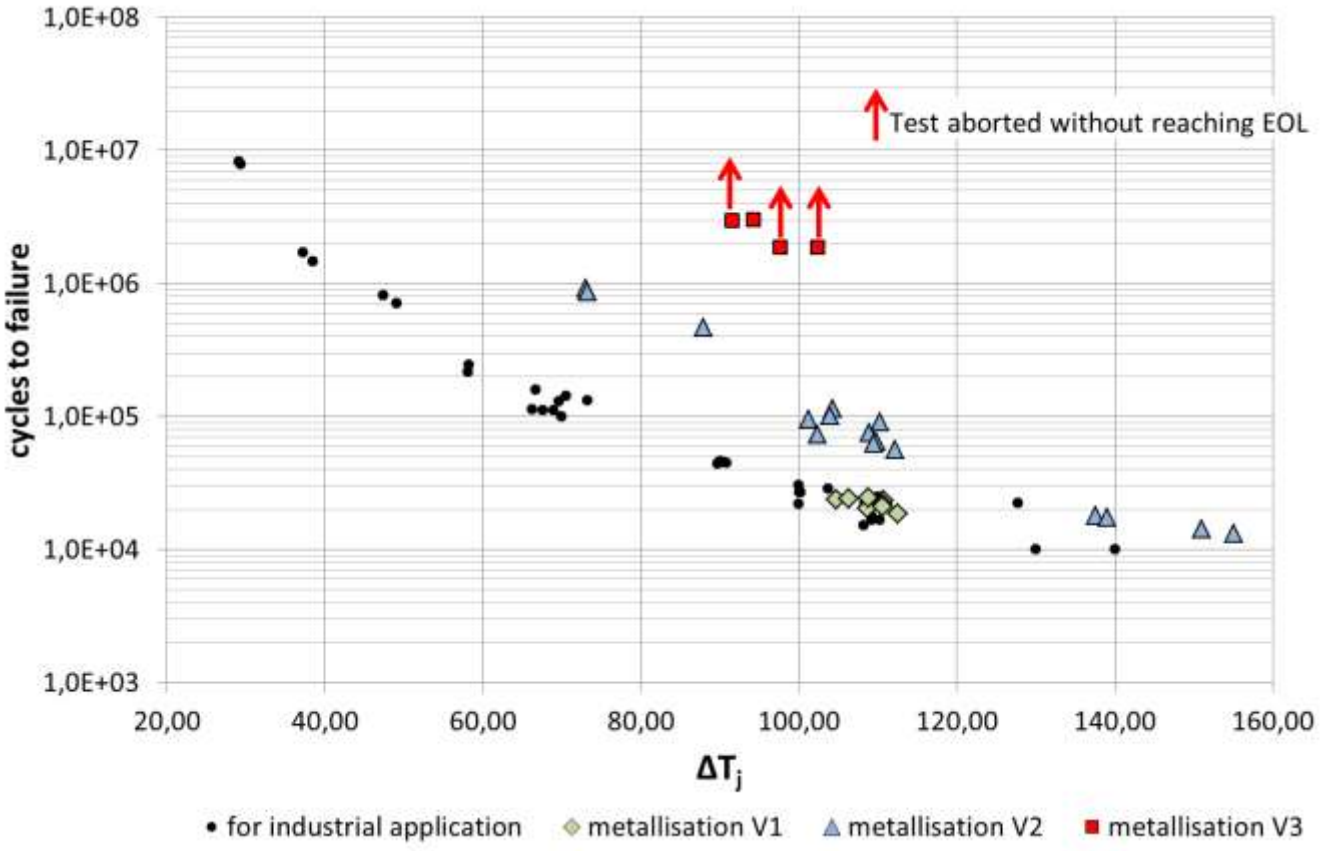
EfA results #3

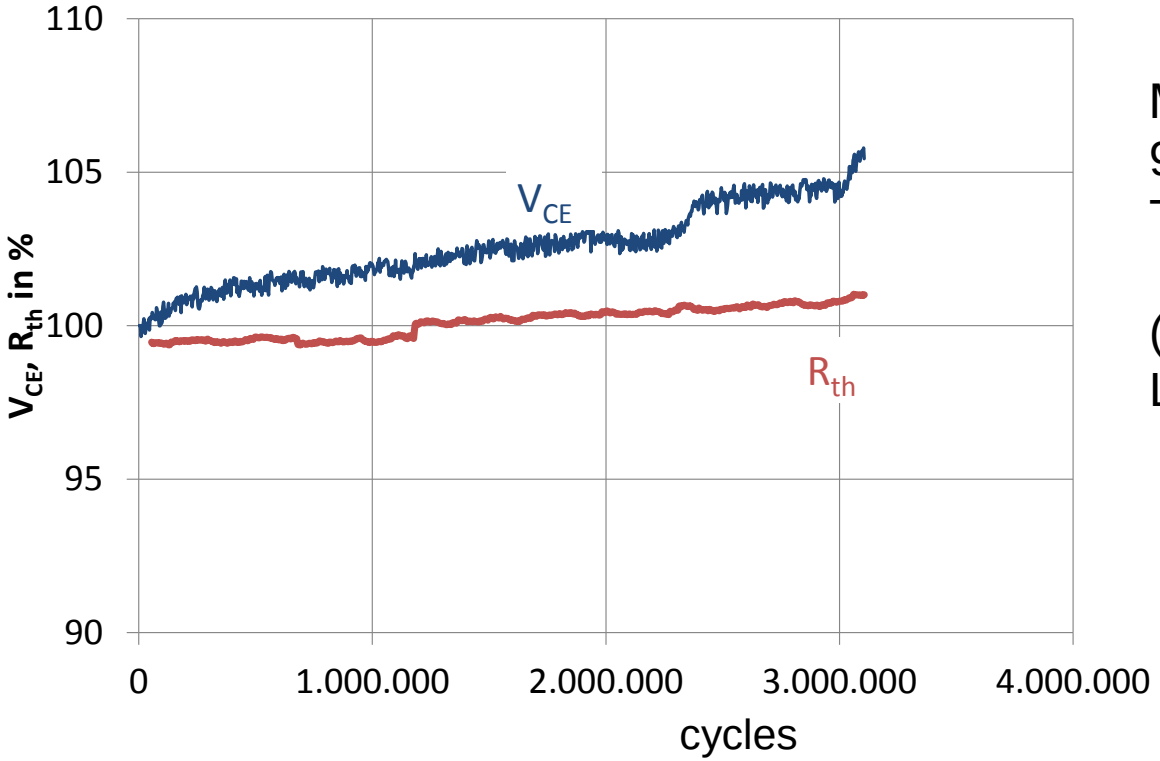
- diffusion soldering
- improved bond wires
- improved chip metallization

$T_{jmax}$ 175°C

(exception ΔT > 130K)



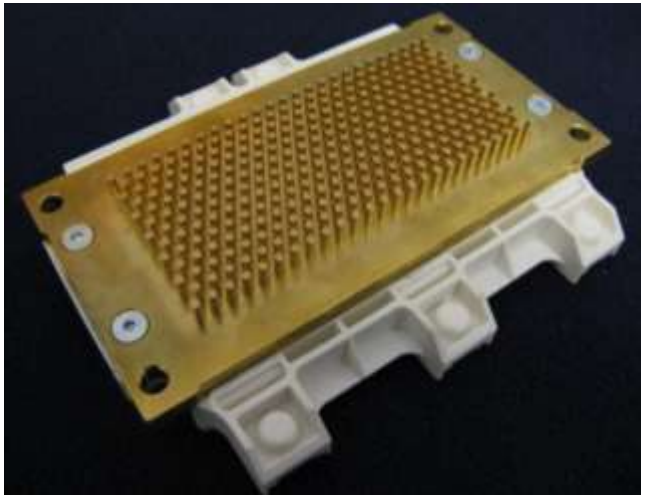
## EfA results #3

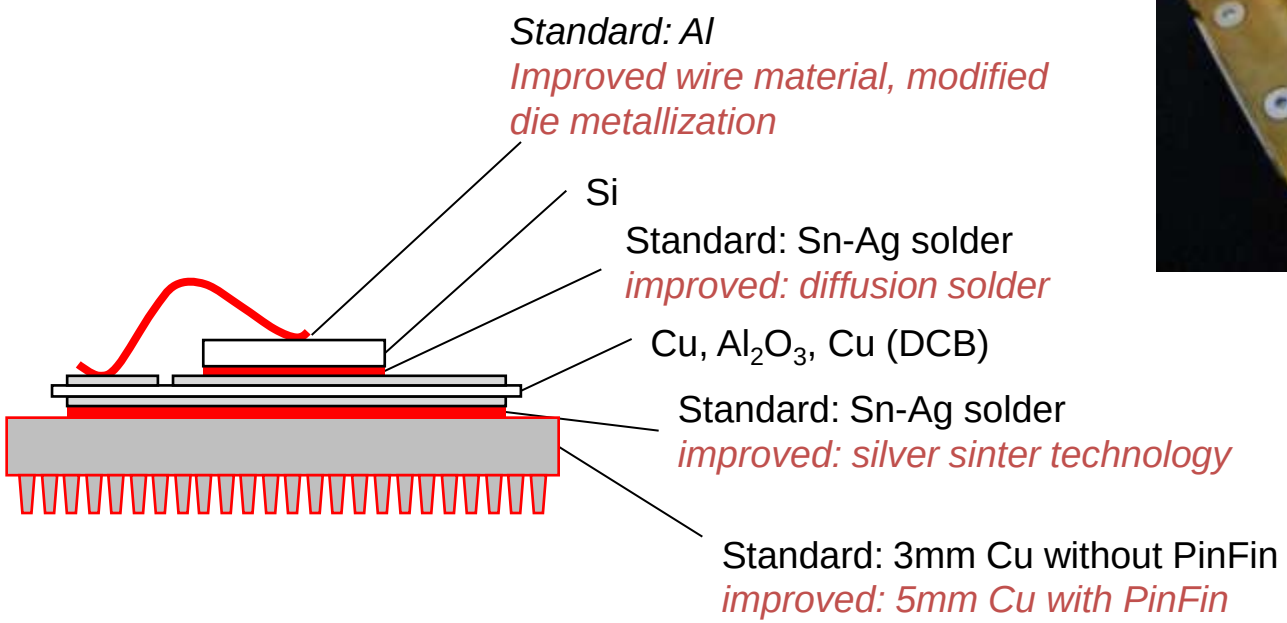



Metallization variant 3, $\Delta T$ = 94K,
$T_{jmin}$ = 83°C, $t_{on}$ = 0.7s

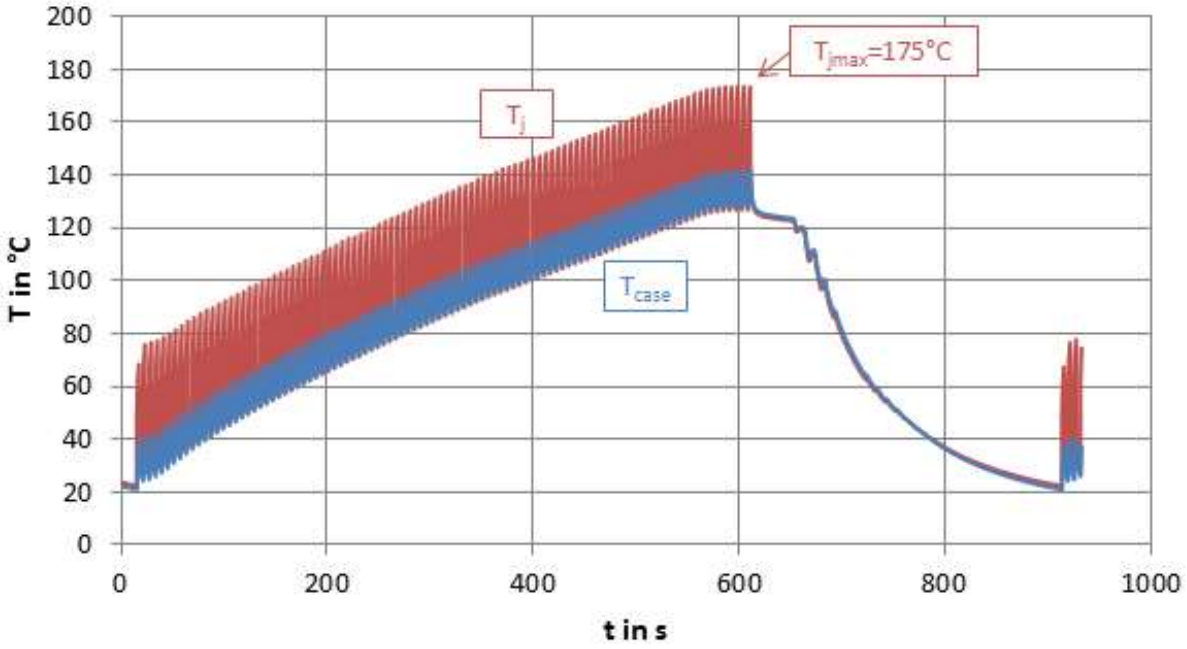
(only sample with End-of-Life)

EfA-results #4





# EfA results #4




Aim: stress to the interconnection Chip - DCB as well as to DCB - base plate

| $T_{water\_min}$ | 22°C |
|---|---|
| $T_{water\_max}$ | 122°C |
| $t_{heating}$ (passive) | 10min |
| $t_{cooling}$ (passive) | 5min |
| $I_{Load}$ | 220A |
| $t_{on}$ (active) | 2s |
| $t_{off}$ (active) | 4s |
| No of active cycles per passive cycle | 100 |
| $T_{jmax}$ (standard-module) | 175°C |
| $T_{jmax}$ (improved module) | 173°C |

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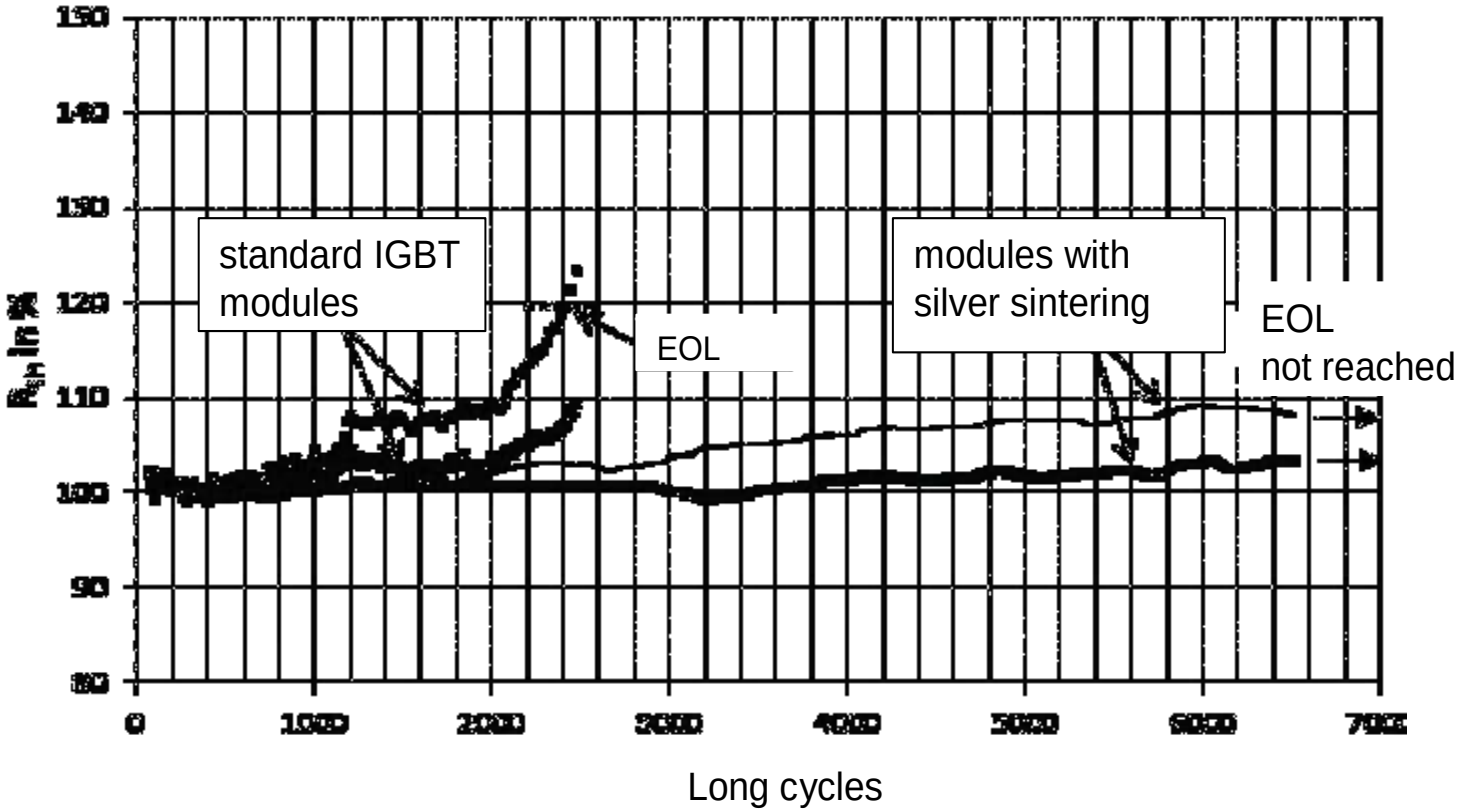
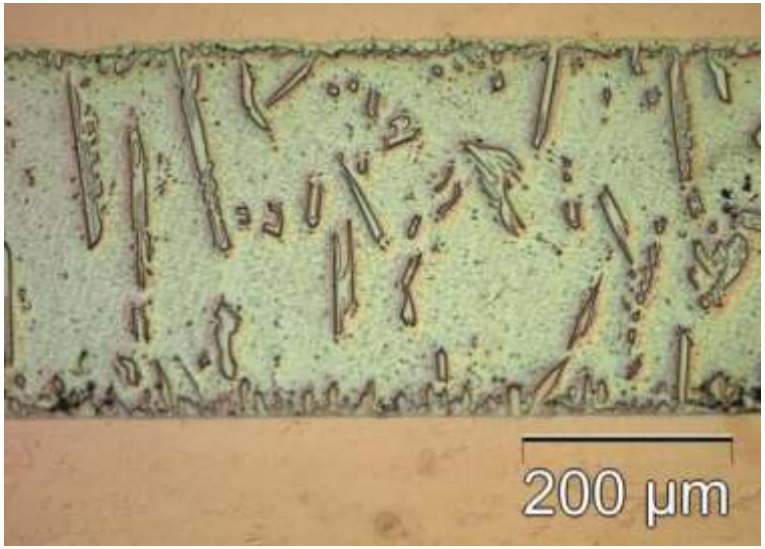
## EfA results #4




Standard technology: failure after 2 400 long cycles, caused by base plate solder layer
New technology: no failure after 6 500 long and 650 000 short cycles

EfA results #5

New solder process substrate to base plate. The new solder layer contains vertical intermetallic phases

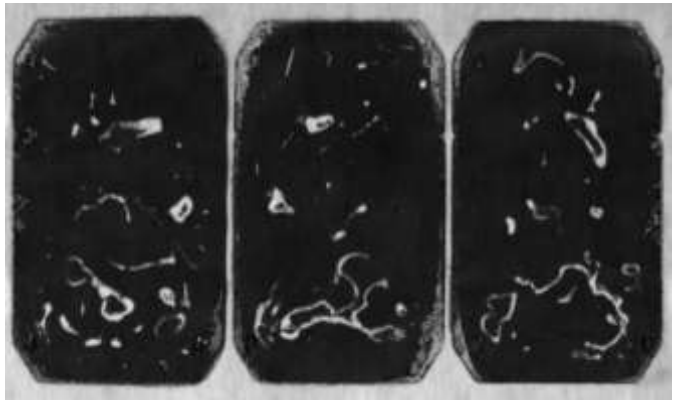



Further: improved bond wires, diffusion soldering identical EfA results #4

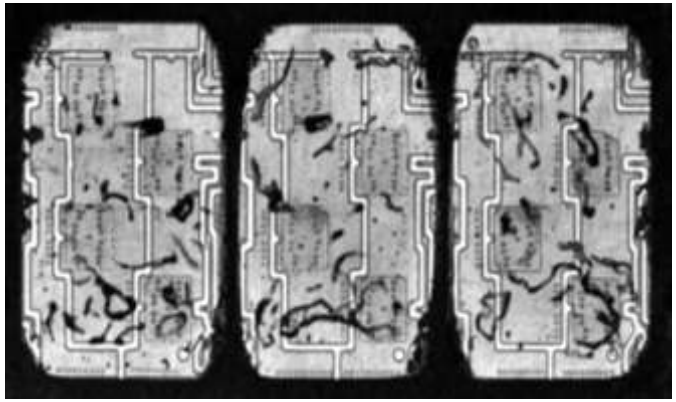
Test conditions: identical EfA results #4

Test after 2100 long cycles aborted for ultrasonic analysis

## EfA results #5



System solder layer



Chip solder layer

Expected lifetime of this solder layer:
> 6500 long cycles

## Summary

Improved bond wires alone give no longer lifetime, considering the used conditions.

Improved chip solder layer (diffusion soldering), improved bond wires and improved metallization leads to a significant longer power cycling lifetime (factor 100 possible)

Additional improved substrate solder layer leads to a very high power cycling capability

The reached power cycling capability shows potential for use of power modules in the cooling circuit of the combustion engine, with $T_{jmax}$ = 200°C.

Packages with SiC devices require improved packaging technology

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