boschman

SALLAND Engineering
Test Technology Center

Salland Engineering: Ag-sintering and its impact on power electronics.

Johan Hamelink, Sept 2019

Table of Content

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I. Introduction

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package development by boschman

assembly services by boschman

equipment by boschman

Package Development:

We research, design and prototype advanced packaging concepts. Together with our customers we develop and assemble innovative, out of the box package solutions.

Typically there are 3 phases: Package conceptualization, Package design and Package Prototyping & & delivery of engineering samples for full qualification.

Assembly Services:

We can manufacture low to medium volume quantities of your qualified products using semi-or fully automatic processes. We offer our assembly services as a separate service or in combination with other services as part of the cycle 'from idea to production'.

Equipment:

Boschman specializes in the development and supply of advanced transfer molding and sintering systems for electronic assembly industries across the globe. We offer added-value encapsulation and bonding process and equipment solutions for a wide range of packages.

II. Sinter background

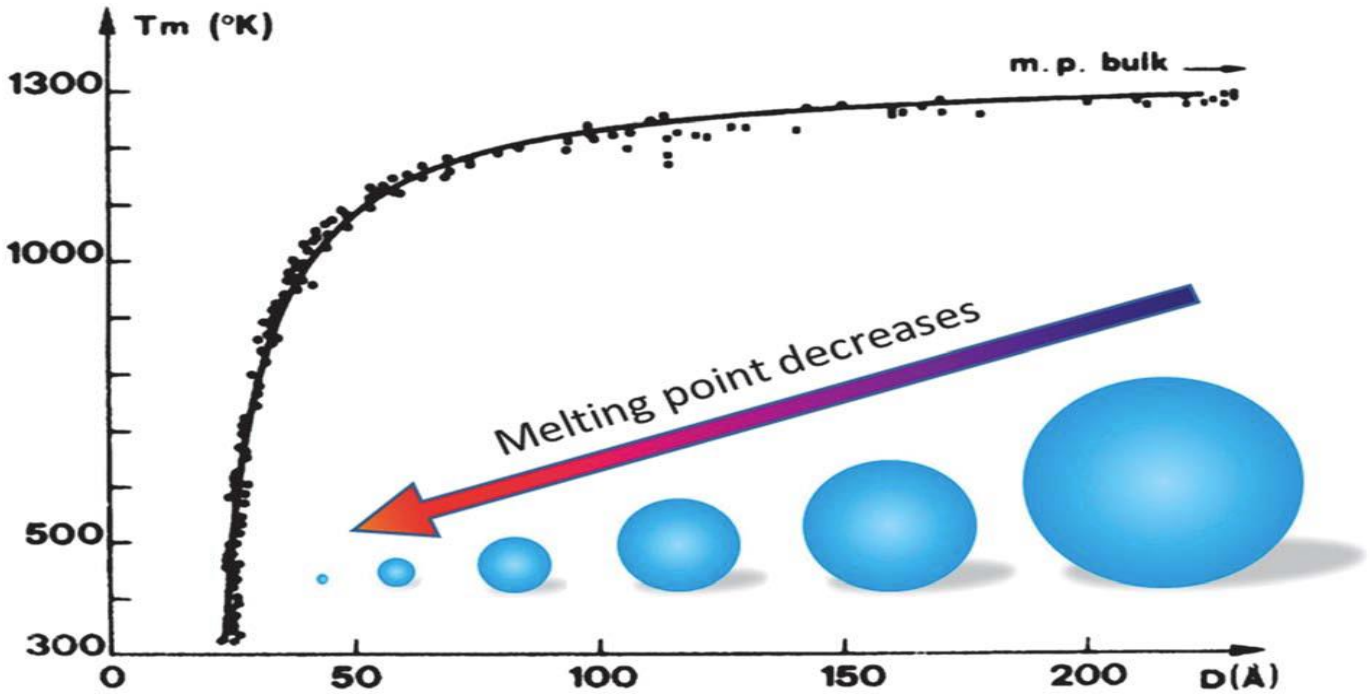
Sintering is a (die) attach technology that unlike eg soldering is based on a low-temperature diffusion process. One of the drivers for application used to be **lead-free (Pb) die-attach**, but recently the **high (thermal) performance** and **reliability** are the main drivers for its application, currently mainly in automotive power electronics.

The technology has been described scientifically from the 1940’s onwards. The application in (power) electronics has been studied from the 1980’s onwards, which spurred material research and development in the 2000’s . From around 2014 onwards the industrial use has been growing very fast.

II. Sinter background

What are metallic nanoparticles and why are they used for sintering?

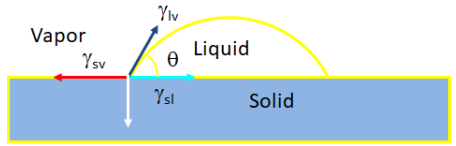
- Yang, C., C. P. Wong and M. M. F. Yuen (2013). "Printed electrically conductive composites: conductive filler designs and surface engineering." Journal of Materials Chemistry C **1**(26): 4052-4069.



Gibbs-Thomson

$$T_{melting} = T_{bulk}\left(1 - \frac{4\gamma_{sl}}{H_f \rho_s d}\right)$$

- Solid-liquid interface energy



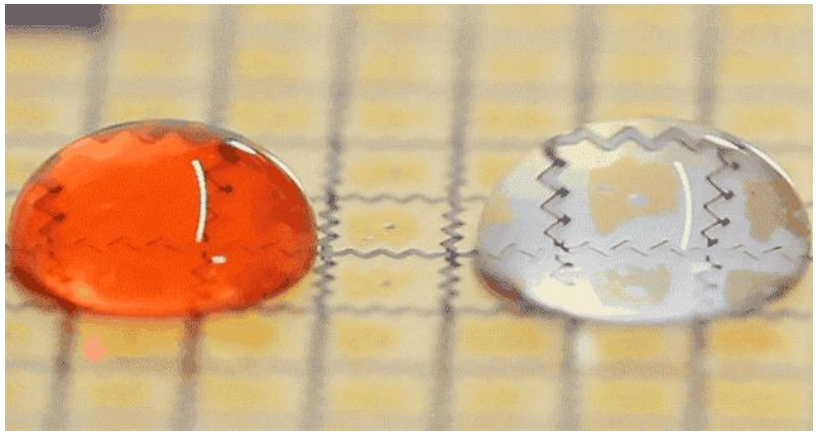
$$\gamma_{sv} - \gamma_{sl} = \gamma_{lv} \cos\theta$$

- Bulk heat of fusion, energy required for phase change

II. Sinter background

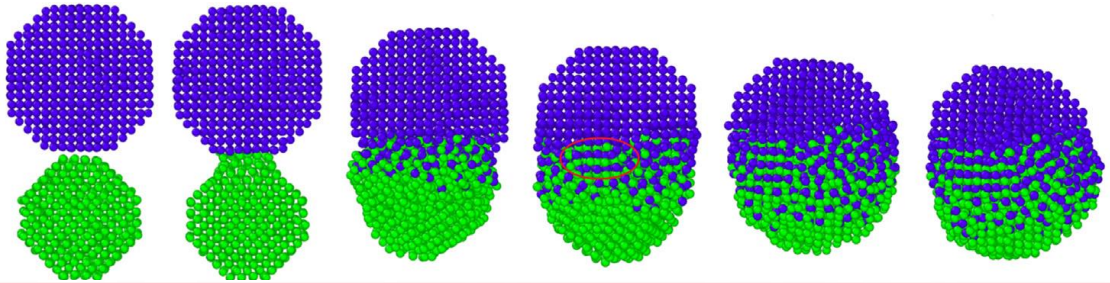
What is the sintering process?

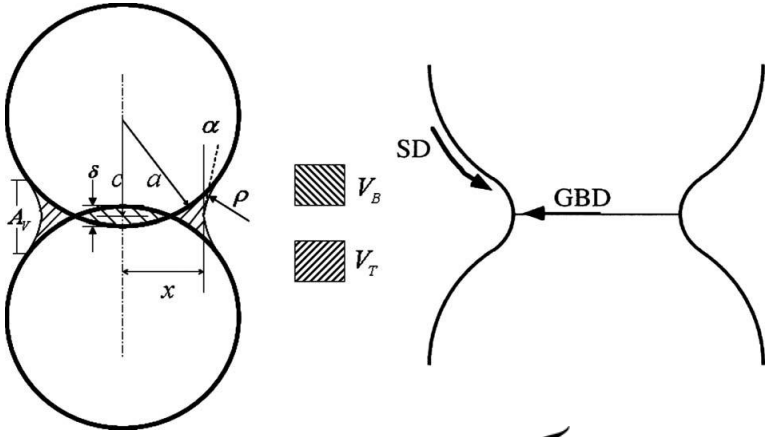
- Yang, L., X. Gan, C. Xu, L. Lang, Z. Jian, S. Xiao, H. Deng, X. Li, Z. Tian and W. Hu (2019). "Molecular dynamics simulation of alloying during sintering of Li and Pb metallic nanoparticles." Computational Materials Science **156**: 47-55.



Diffusion Process

- Lattice diffusion within the particle
- Surface diffusion along the particle
- Through-lattice diffusion across the particle
- Grain boundary diffusion across the particle





II. Sinter background

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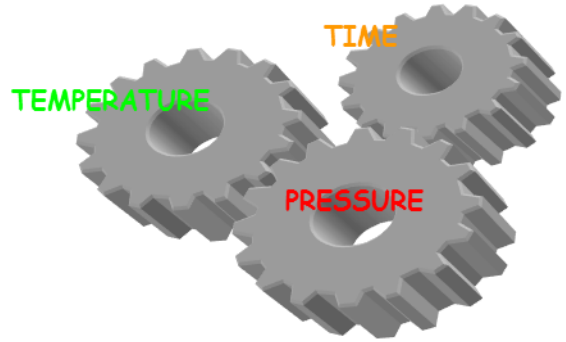
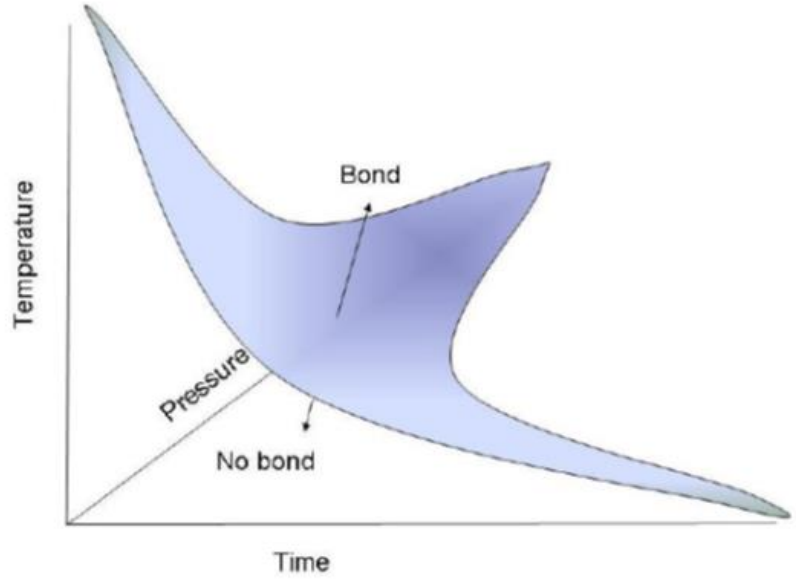
Typical process parameters





For Ag sintering

- Pressure: 15 – 25 Mpa
- Temperature: 230 – 270 C
- Time: 60 – 90 seconds

II. Sinter background

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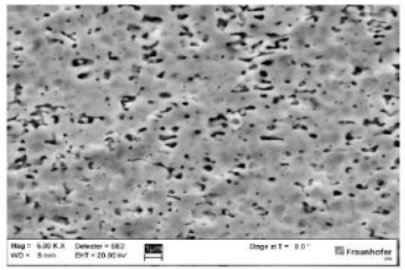
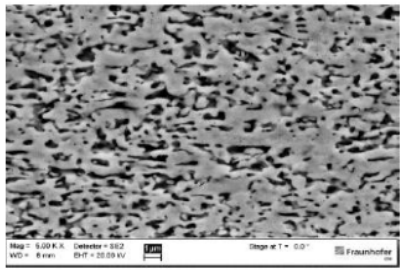
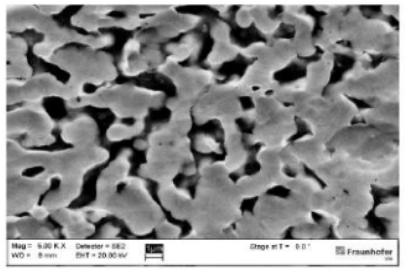
Pressure Is Densifying The Dry And Porous Paste

FACHHOCHSCHULE KIEL
HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN
University of Applied Sciences

30 MPa	10 MPa	No pressure
		
TC: ca. 260 W/mK ME: ca. 60 GPa	ca. 160 W/mK ca. 30 GPa	ca. 60 W/mK ca. 10 GPa

Source: FHG-ENAS, ProPower 2012

Aim and achievements of pressure sintering:

- Significantly improved thermal conductivity (TC) → **Power**
- Maximize modulus of elasticity (ME) and shear strength → **Reliability**
- Shorting sintering time → **Process time**

III. Performance and reliability

Double Side Sintered IGBT 650V/ 200A in a TO-247 Package for Extreme Performance and Reliability

Gustavo Greca, Paul Salerno, Jeffrey Durham, Dr. Francois Le Henaff [(1)], Jean Claude Harel [(2)], Johan Hamelink [(3)], Weikun He[(4)]

[1]Alpha Assembly Solutions, 109 Corporate Boulevard South Plainfield NJ 0890, USA

[2]Renesas Electronics America (REA), 2801 Scott Blvd, Santa Clara, CA 95050 USA

[3]APC/ Boschman - Stenograaf 3, 6921 EX Duiven, The Netherlands

[4]Mentor Graphics 46871 Bayside Pkwy, Fremont, CA 94538 USA

2016 18th Electronics Packaging Technology Conference

III. Performance and reliability

Renesas TO-247 performance + ~50%

Fig.5: Thermal resistance comparison between classic TO247 and new component.

The standard TO247 components were powered with 130A to reach 85°C delta T°C, during 15s and then to a 15s relaxation period. The double side sintered TO247 were summited to 200A during 15s and then to a 15s relaxation period in order to achieve same 85°C delta T°C. Both components are subjected to a gate voltage of 20V. To evaluate a higher delta T°C, the double side sintering components were also summited to a 15V gate voltage to dissipate more power and achieve 100°C. When submitted to 200A, the new components achieved Tj max °C (maximum junction temperature) between 142 to 145°C. The standard components achieved the same temperature when summited to 130A.

III. Performance and reliability

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Renesas TO-247 reliability >12x !!

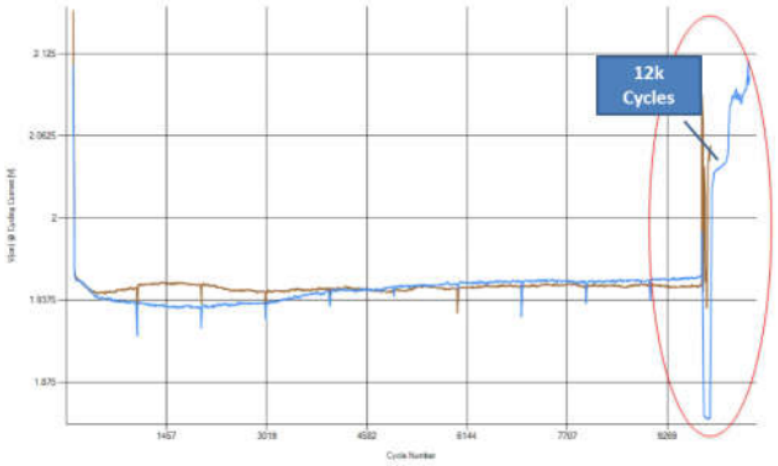

Fig.6: Vce continuous measurement during active power cycling test for soldered components, 2 best cases presented. Failure by 12k cycles, demonstrated by a spike on the Vce value, typical signature of wiring bond defect.

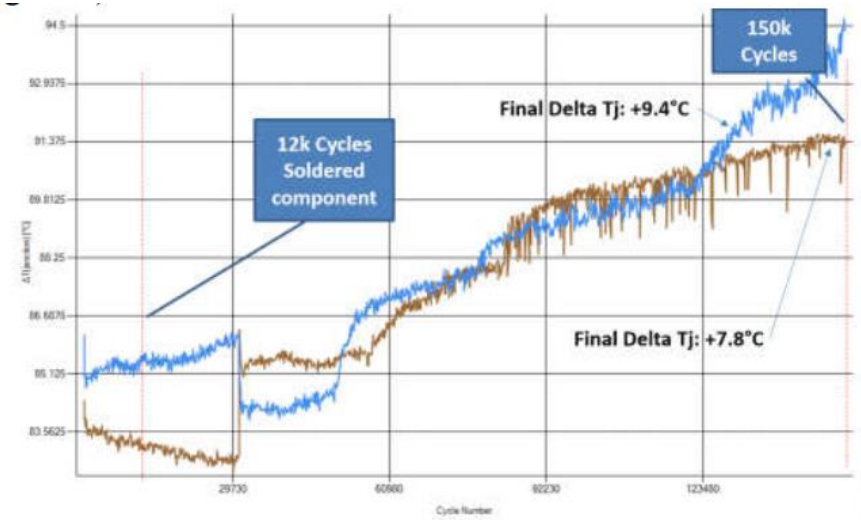

Fig.8: Delta T°C results after active power cycling test for sintered components, 2 worst cases presented. No failure arriving till 150k cycles. Minor increasing on the measurement is coming from grease "pumping out" phenomena.

IV. Electrical power

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GLOBAL ENERGY CONSUMPTION

Expected to double from ~500 Exajoules in 2015 to ~1.000 Exajoules by 2100 with a shift in Energy Mix from ~20% to ~60% Electricity

GLOBAL POPULATION

Increased from 2,5Bn to 7,0Bn between 1950 to 2015 and is expected to increase to 10Bn by 2100.

"THE GREAT CONVERGENCE"

TECHNOLOGICAL ADVANCES

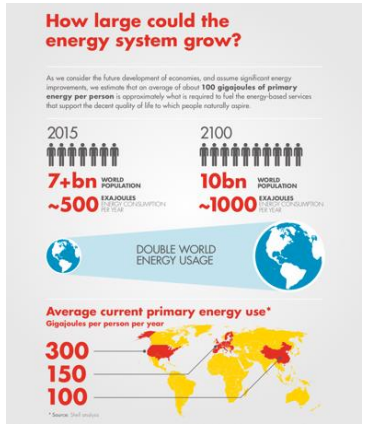
First Electric Car was developed in 1828 by Ányos Jedlik.

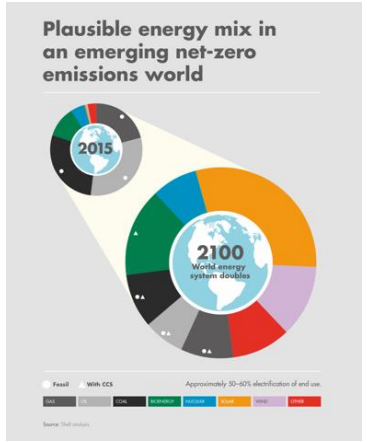
190 years later, Tesla presented the Model S with a range of ~600km

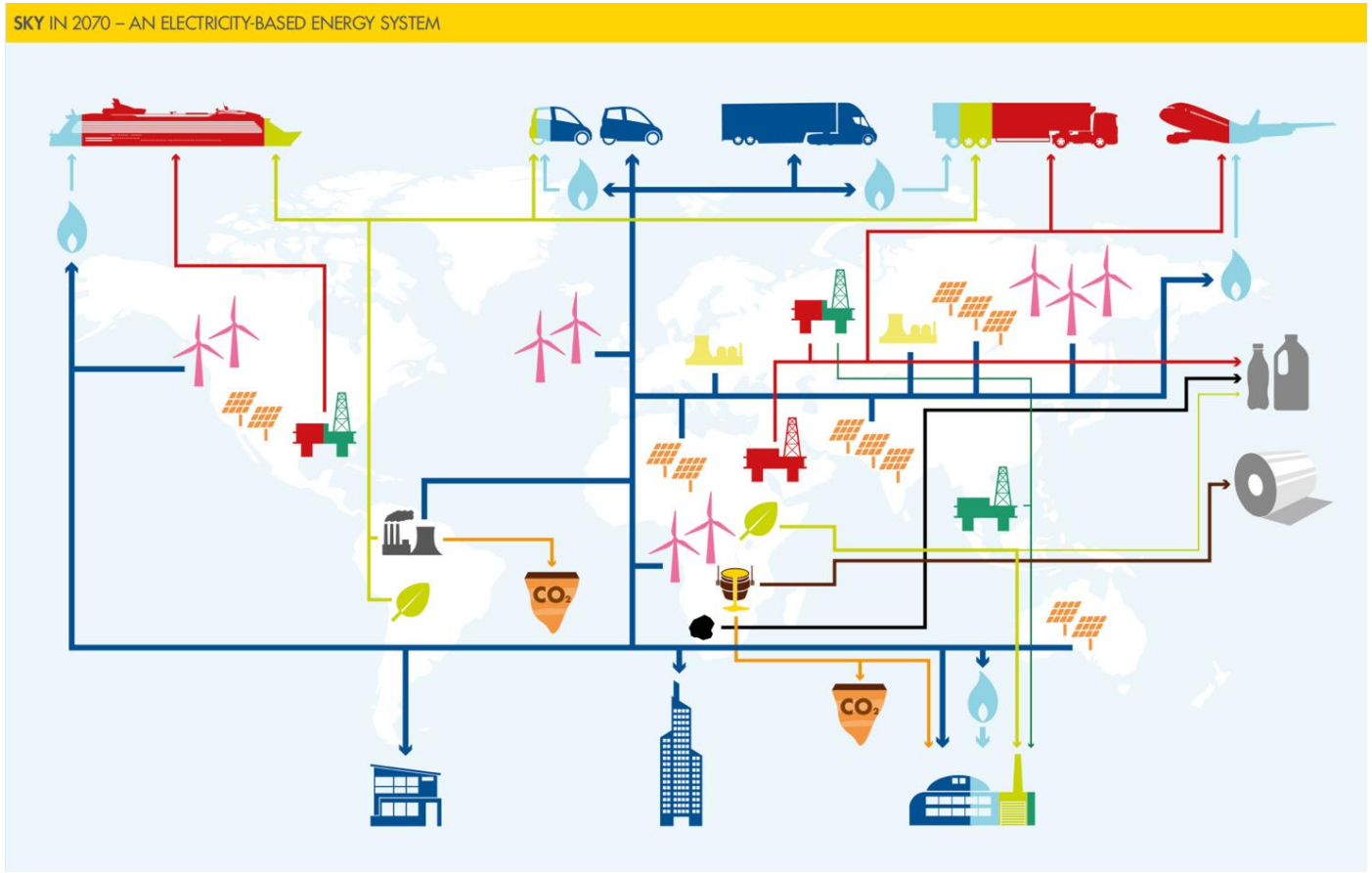
CLIMATE CHANGE

Paris Agreement (Dec 12th, 2015) aims to keep global temperature rise this century below 2°C above pre-industrial levels.

IV. Electrical power

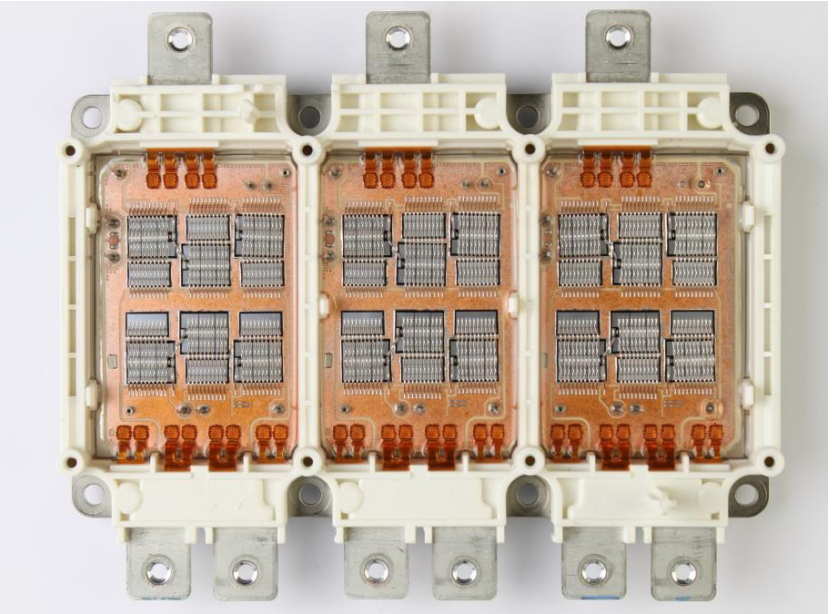






COURTESY SHELL

V. Trends in (automotive) power

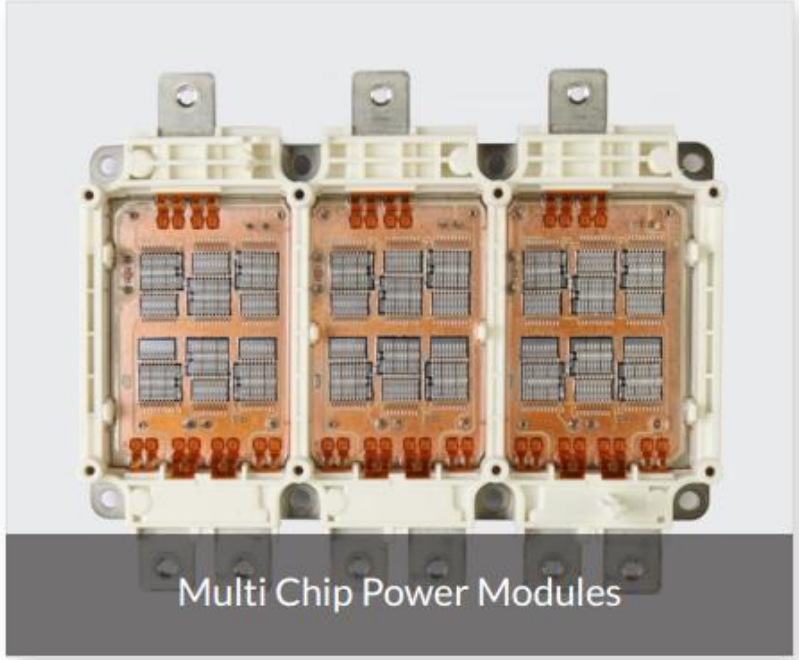


* Infineon Technology – Hybridpack drive – Courtesy of System Plus Consulting 2019

- Replace solder by sinter material: more performance, higher reliability
- Replace wire-bond by ribbon bond or clip: lower parasitic inductance and higher reliability
- Replace potting material by epoxy molding compound: better CTE match, higher thermal conductivity, higher reliability
- Improve geometry, especially for double-sided cooling
- Reduce form-factor to reduce cost

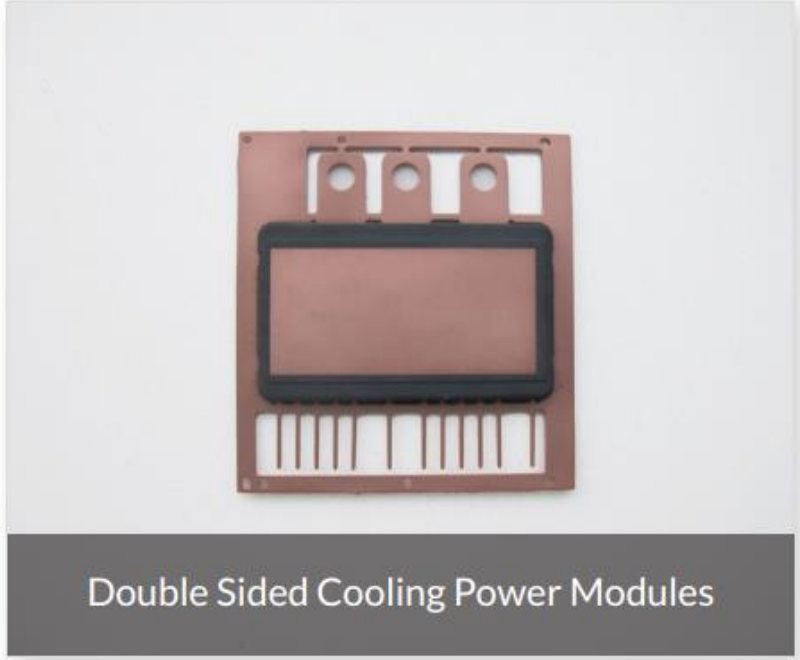
V. Trends in (automotive) power

Existing trends



Multi Chip Power Modules

Modular Power Discretes



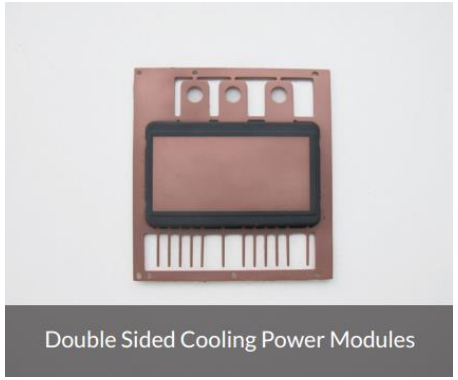
Double Sided Cooling Power Modules

* Infineon Technology – Hybridpack drive – Courtesy of System Plus Consulting 2019

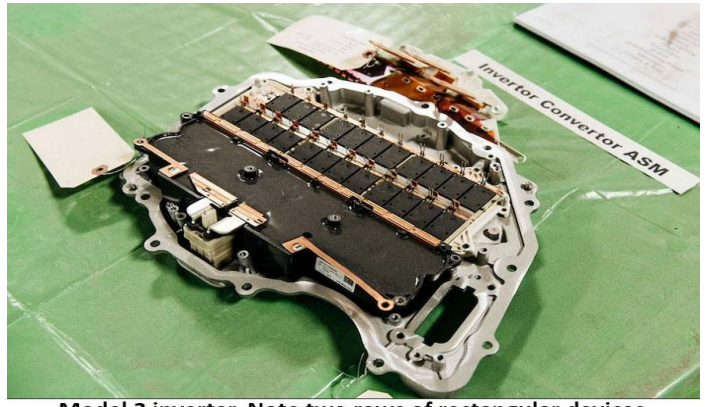
V. Trends in (automotive) power

Why 2 trends?

- Scalable: easy to multiply power by using more units



- Economical: optimal cost (form-factor) and economy-of-scale for one solution



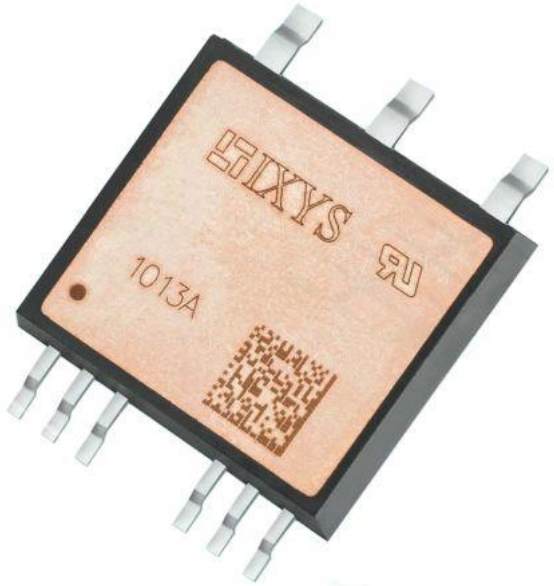
Model 3 inverter. Note two rows of rectangular devices

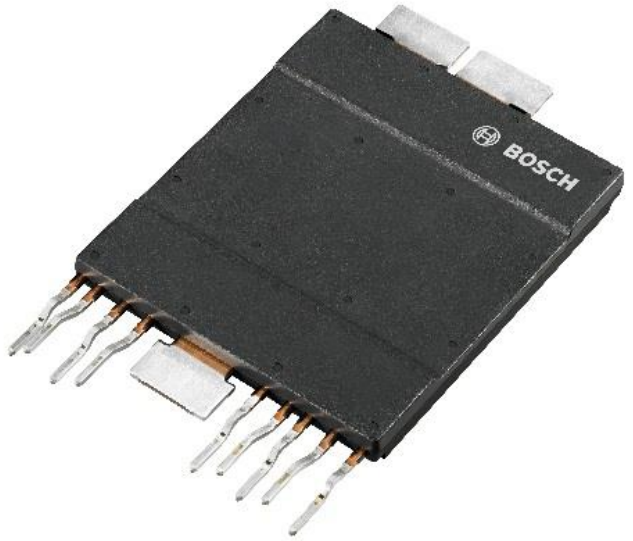
Taken from Motor Trend photos of Munro Ass. teardown

Pictures from internet: assessed July 29th 2019

V. Trends in (automotive) power

Most popular solution at present…

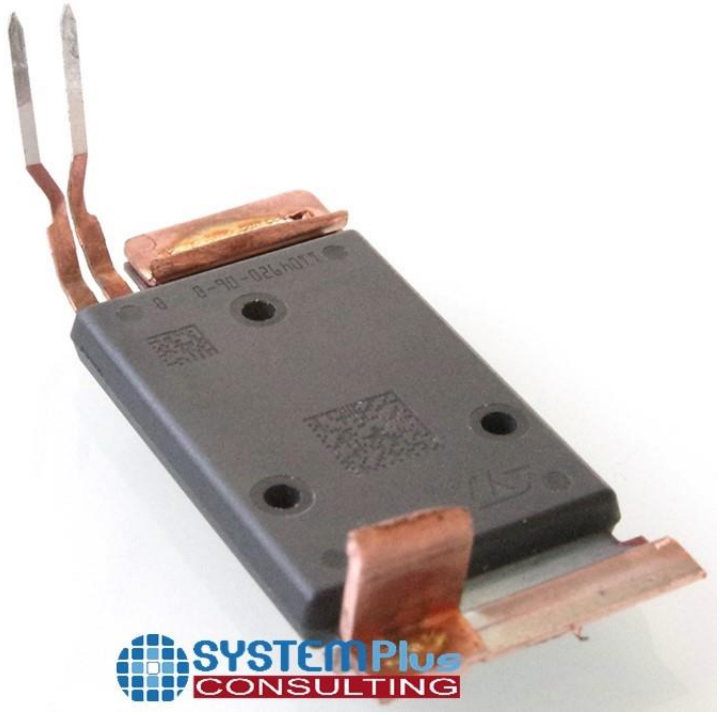




Pictures from internet: assessed July 29th 2019

V. Trends in (automotive) power

But…STPAK gets traction!



life.augmented

SCT200N120G2PAG

Target - Datasheet

Automotive silicon carbide Power MOSFET 1200 V, 150 A
15 mΩ (typ., T_J = 25 °C) in STPAK packing

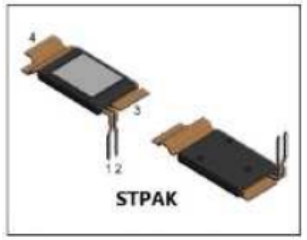
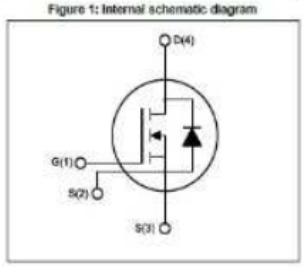


Figure 1: Internal schematic diagram



Order code	V_{DS}	$R_{DS(on)}$	I_D
SCT200N120G2PAG	1200	0.015 Ω	150 A

Features

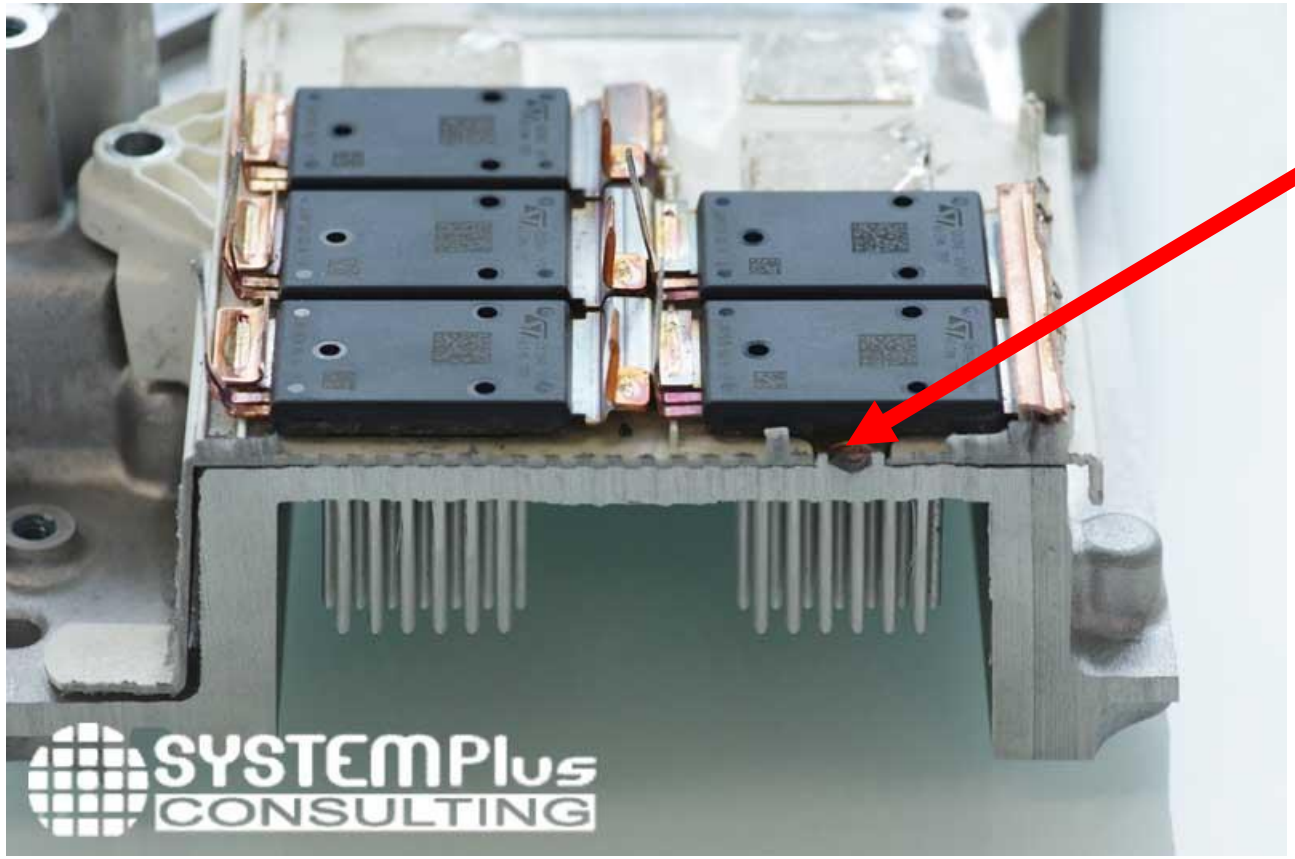
- AEC-Q101 rev.D qualified
- Very fast and robust intrinsic body diode
- Low capacitance
- Multi sintering
- Low thermal resistance
- Very High operating temperature capability

Applications

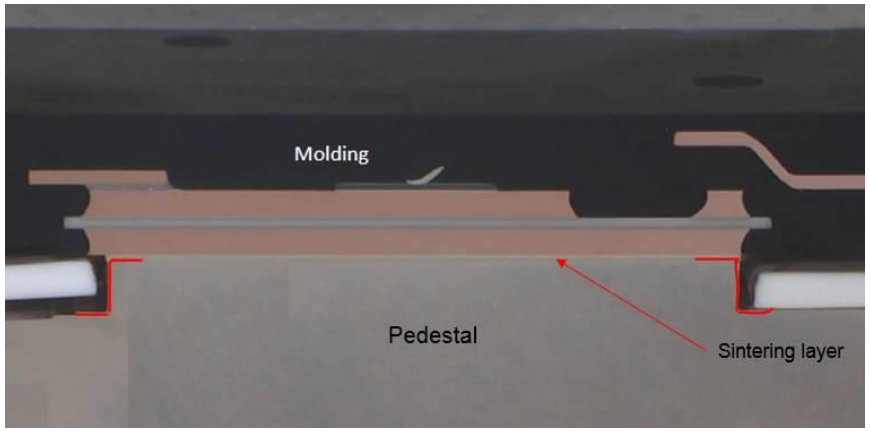
- Traction Inverter
- DC-DC converters
- Motor drives

V. Trends in (automotive) power

2nd level sintering

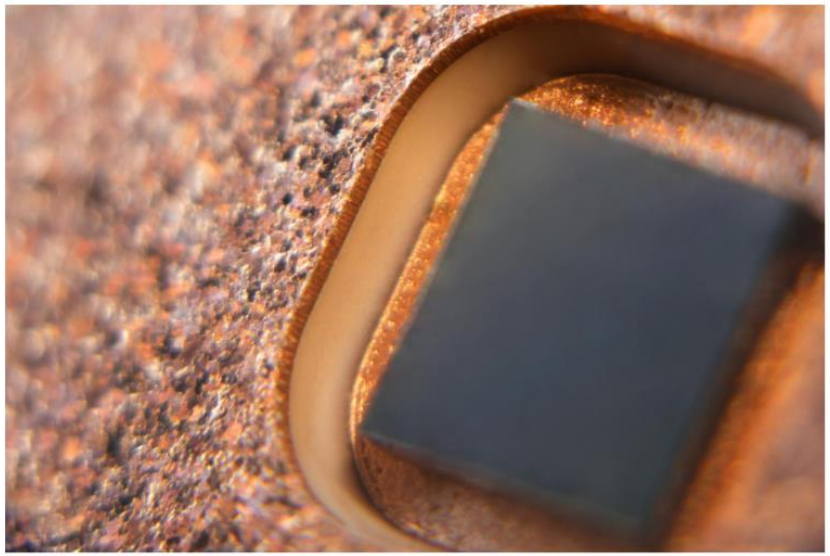


Sinter the package into the (inverter) housing.



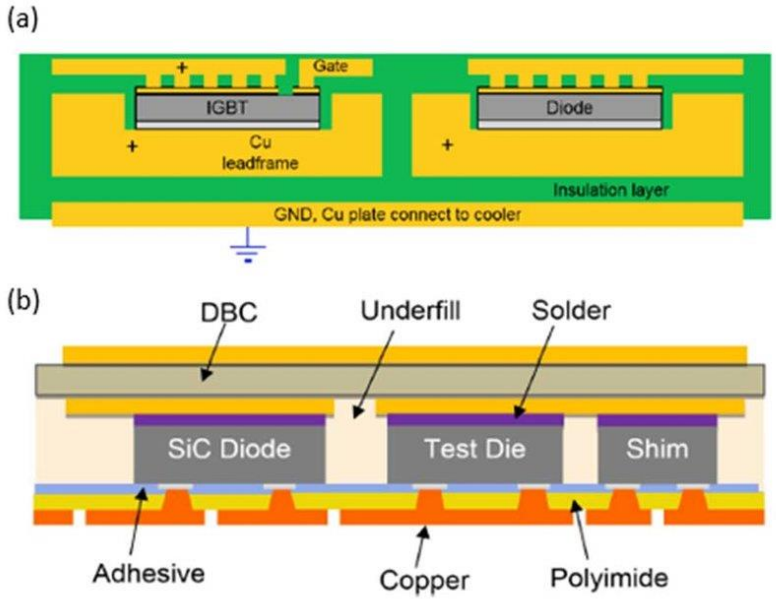
V. Trends in (automotive) power

New upcoming trend: embedded



Close-up view of a wide-bandgap device embedded by the Ceramic Embedding technology.
© Fraunhofer IISB

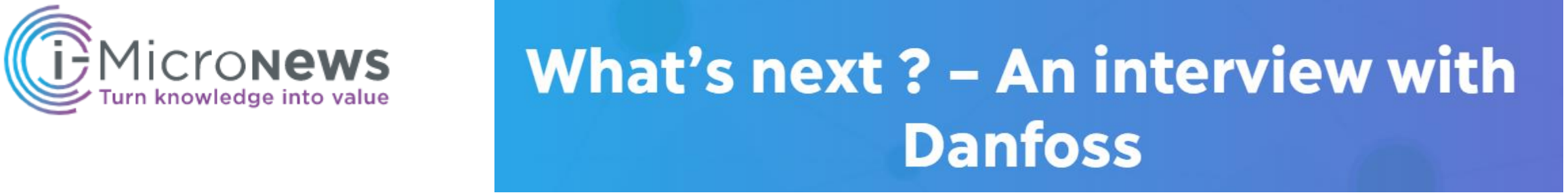
Power embedded in ceramics (DBC)
Fraunhofer IISB



Power embedded in PCB (p2-pack) (a)
Schweizer Electronics AG

V. Trends in (automotive) power

Spill-over to industry



"We expect to see a technology spill-over from automotive into industrial applications following the high demands and volumes from e-mobility. In other words, we expect the automotive segment to become the key driver for power module technology development going forward, but that the advances will spread to other segments with time. We are consistently working on transferring the latest technologies from automotive and applying them in industrial and renewable applications when it makes sense."

Mette Nordstrom, Strategy, Marketing and Communication Director Danfoss.

VI. Conclusions

Summary

- Ag-sintering is a proven and accepted new technology that provides cost advantages, performance and reliability.
- The electrification of cars is ramping up and is driving the development of new and advanced solutions in power electronics using Ag-sintering.
- Innovations in the electrification of cars will in turn drive enabling solutions and reliability throughout the entire electronic supply chain

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Literature

Die-Attach Materials for High Temperature Applications in Microelectronics Packaging

Materials, Processes, Equipment, and Reliability

Editors: **Siow**, Kim Shyong (Ed.)