

MATERIAL SOLUTIONS FOR HIGH-RELIABILITY AND HIGH-TEMPERATURE POWER ELECTRONICS

CENTRE FOR POWER ELECTRONICS CONFERENCE
Virtual session; October 13th, 2021 ; Aarief Syed-Khaja



FOCUS TOPICS

- TRENDS INFLUENCING POWER ELECTRONICS AND PACKAGING
- REQUIREMENTS FOR HIGHER RELIABILITY AND THERMO-MECHANICAL STABILITY
- MATCHED MATERIAL INTERCONNECT SYSTEMS
- DESIGN INTEGRATION AND PROCESS CHALLENGES

CONTENT

1 | HERAEUS GROUP

- › Heraeus Business Portfolio
- › Heraeus Electronics

2 | HERAEUS AND CHALLENGE OF NEW PACKAGING SOLUTIONS

3 | CHALLENGE PERFORMANCE

- › DTS®, sintering and Cu bonding technology for increased lifetime and current/power density
- › Si₃N₄ AMBs for enhanced heat dissipation and reliability

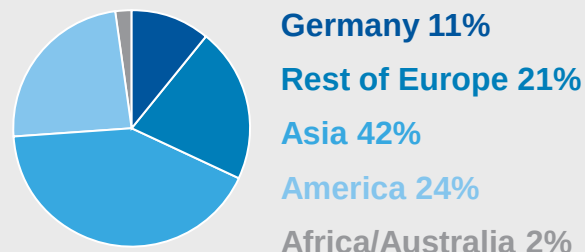
4 | CHALLENGE QUALITY AND YIELDS

- › DTS for reduced production complexity
- › Pre-applied sinter paste for reduced complexity and improved yields

5 | CHALLENGE TIME TO MARKET

- › Cooperation for quicker time to market
- › Engineering services for accelerated qualification and testing

GLOBALLY SUCCESSFUL PORTFOLIO COMPANY



RESEARCH & DEVELOPMENT
expenditures

7%



Based on revenues excl. Precious Metals

11 market-oriented
GLOBAL BUSINESS UNITS

TOP 10
FAMILY-OWNED COMPANIES
in Germany

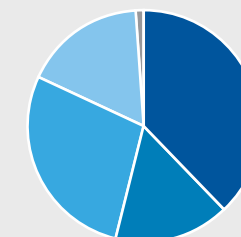
Listed in
FORTUNE 500



More than
SITES **100**
in
COUNTRIES **40**



14.800
EMPLOYEES



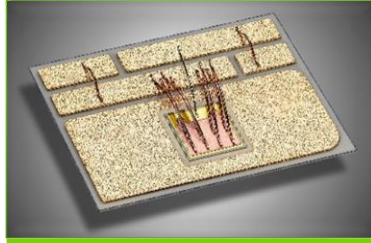
Germany 37%
Rest of Europe 17%
Asia 28%
America 17%
Africa/Australia 1%

including staff leasing

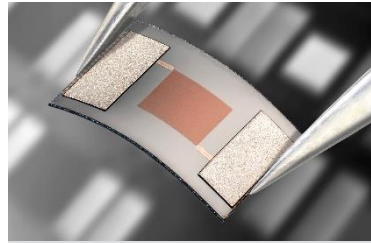
BUSINESS PORTFOLIO – LEADING IN GLOBAL MARKETS



**Heraeus
Precious
Metals**



**Heraeus
Electronics**



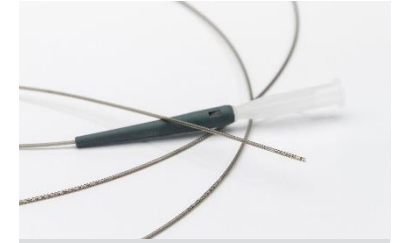
**Heraeus
Nexensos**



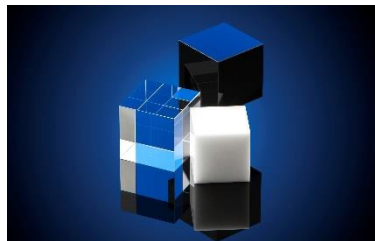
**Heraeus
Epurio**



**Heraeus
Medical**



**Heraeus
Medical
Components**



**Heraeus
Conamic**



**Heraeus
Comvance**



**Heraeus
Noblelight**



**Heraeus
Electro-Nite**



**Heraeus
Photovoltaics**

OUR PORTFOLIO AT A GLANCE



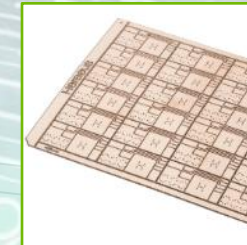
Sinter Materials

- mAgic® sinter paste for power modules, discretes and amplifiers



Bonding Wires

- Copper and coated-copper wire
- Gold and silver wire
- Thick wire and ribbons (aluminum and copper)



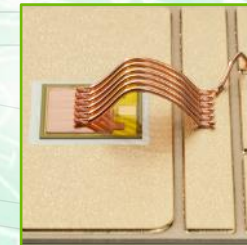
Metal Ceramic Substrates

- Condura®.classic – DCB- Al_2O_3
- Condura®.extra – DCB-ZTA
- Condura®.prime – AMB- Si_3N_4
- Condura® +



Solder Materials

- Die attach solder paste and wire
- SMT solder paste
- Solder powder
- Solder paste for advanced packaging, SiP



Material Systems

- Die Top System (DTS®)
- DCB with pre-applied solder



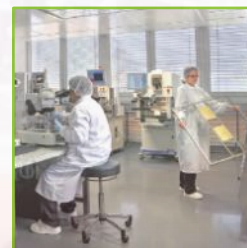
Adhesives

- Conductive adhesives
- SMT adhesives



Thick Film Pastes for

- Hybrid integrated circuits
- Heater circuits
- Sensor applications
- Passive components



Engineering Services

- Prototype design and assembly
- Simulation
- Material analysis
- Testing and Qualification

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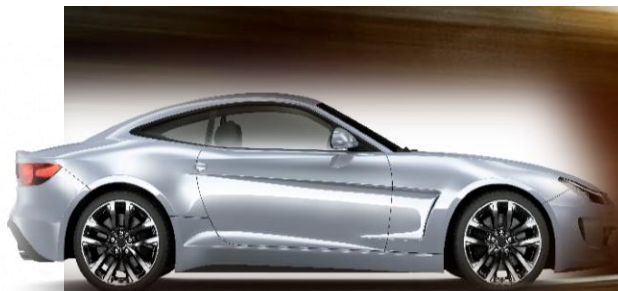
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REVOLUTION OF POWER ELECTRONICS PACKAGING

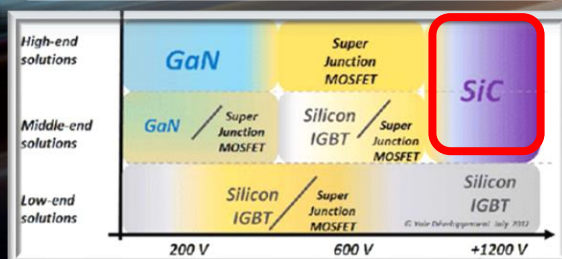


Increase Power
Increase Efficiency
Decrease form factor



Higher traveling
distance per charge

WBG Material



Operating Temperature

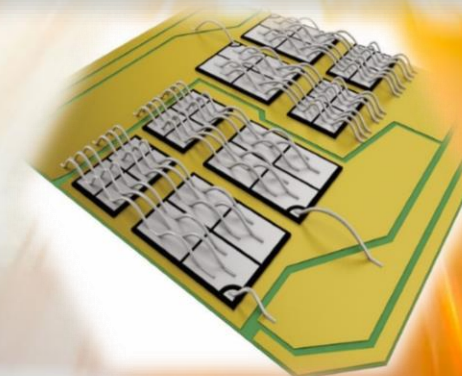
Up to
150°C

More than
175°C

Si

SiC

Matching Assembly
Material



Traditional assembly and packaging
materials have reached its limits.

REVOLUTION OF POWER ELECTRONICS PACKAGING

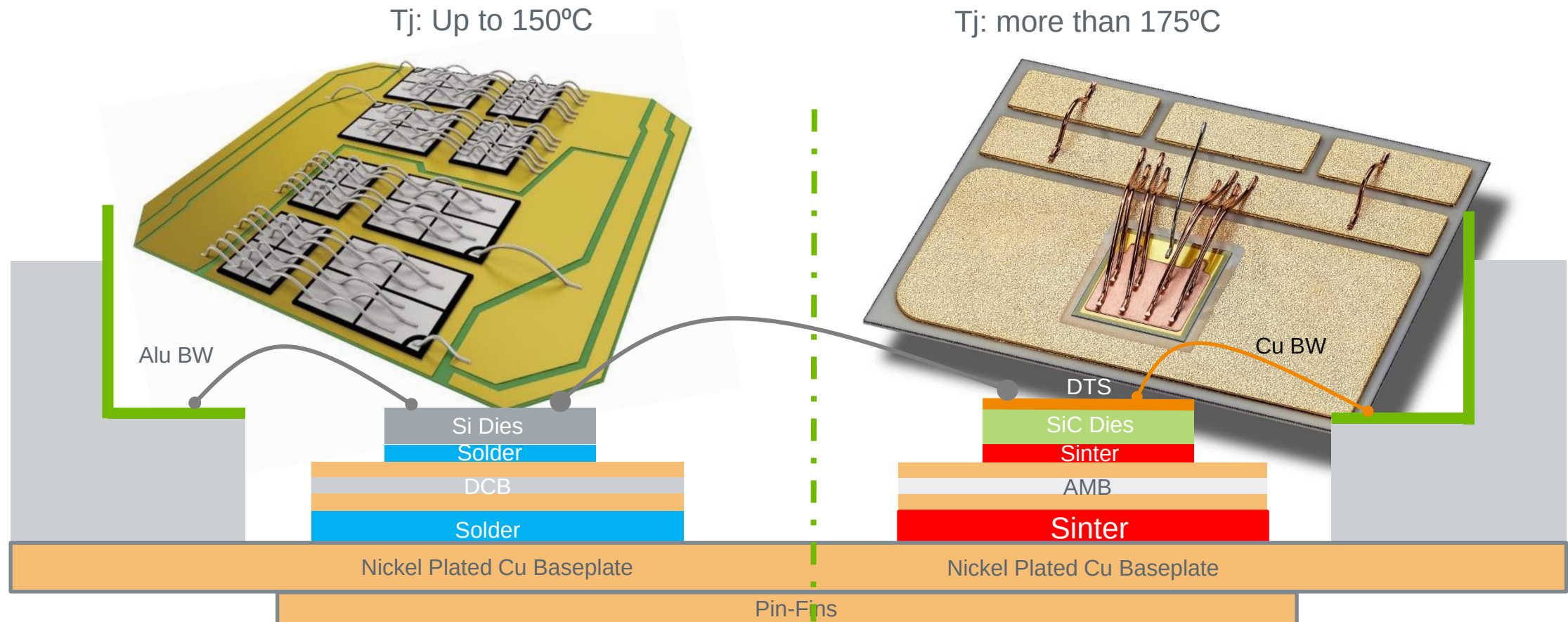
TRANSITION TO HIGH POWER DENSITY IGBT MODULE PACKAGING

Present

T_j : Up to 150°C

Future

T_j : more than 175°C



POWER SEMICONDUCTORS AND NEED FOR NEW PACKAGING MATERIALS SOLUTIONS

Smaller and Thinner Dies

Increased Power Density

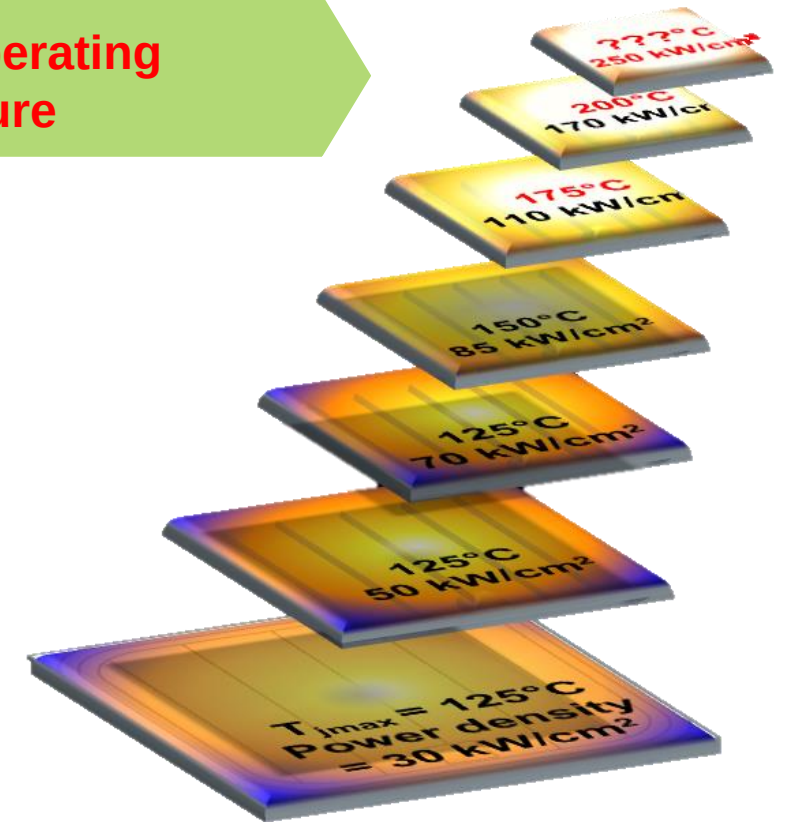
Higher Operating
Temperature

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

HERAEUS AND THE CHALLENGES OF NEW PACKAGING SOLUTIONS FOR POWER MODULES

CHALLENGES

How to increase lifetime?

How to increase current and power density?

How to increase heat dissipation?

PERFORMANCE

How to reduce production complexity?

How to increase robustness of production processes?

How to reduce 2 production steps out of 4 ?

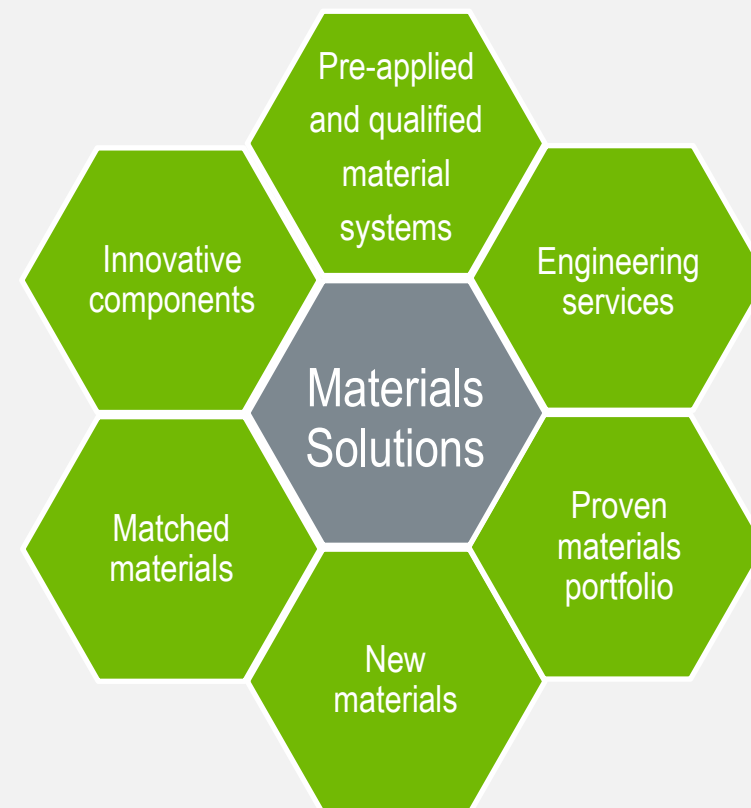
QUALITY & YIELD

How to speed up the industrialization?

How to reduce material development time?

TIME TO MARKET

HERAEUS SOLUTIONS



MARKET CHANGE: THE ELECTRONIC MARKET CONTINUES TO EVOLVE



New technology requirements challenge the industry

Material lifetime requirements: 10x higher

Heraeus Die Top System (DTS®) increases the lifetime of devices up to ten times

Operating temperatures: $\geq 200^{\circ}\text{C}$

Heraeus mAgic® Silver Sinter Pastes withstands highest temperatures

Packaging feature sizes: $< 30\mu\text{m}$

Heraeus Welco® Fine Pitch Solder Pastes offer best-in-class reliability and workability

Cost breakthrough for mass adoption

Heraeus AgCoat® Prime Gold Coated Silver Bonding Wire ensures high performance at reasonable costs

Environmentally friendly materials

Heraeus gold bonding wire uses certified recycled gold

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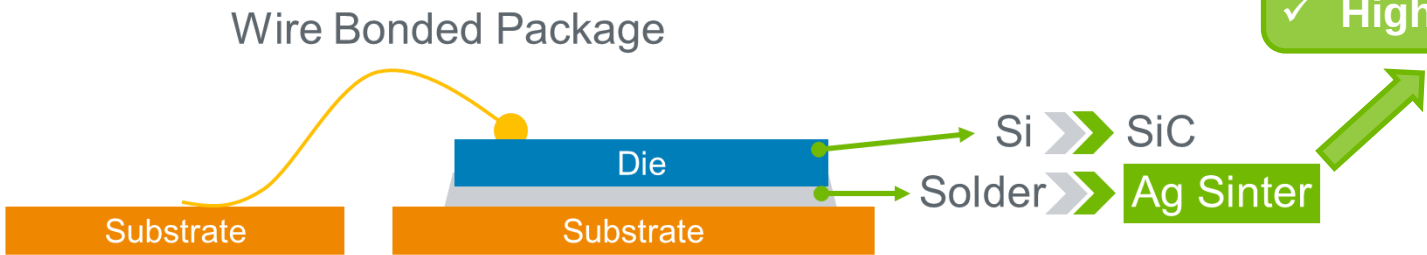
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WHY SINTERING?

High Power Packages Development Trend
Higher current capacity >>> Higher operating temperature >>> Higher reliability



- ✓ High melting temperature (961°C)
- ✓ High thermal and electrical conductivity

“Integration of new materials and technologies with increase in reliability”

Die Attach Materials	Lead-free solder Sn _{96.5} Ag _{3.5}	High-lead solder Pb _{92.5} Sn ₅ Ag _{2.5}	Silver sinter
Max. operation temp. (°C)	220	296	> 380
Thermal conductivity (W/mK)	60	25	> 150
Electrical conductivity (MS/m)	8	5	40
CTE (ppmK ⁻¹)	25	29	20
Young's modulus (kN/mm ²)	30	23.5	40-55

PRESSURE SINTER PASTE PROCESS & APPLICATION

mAgic Paste Pressure Process

Paste Printing

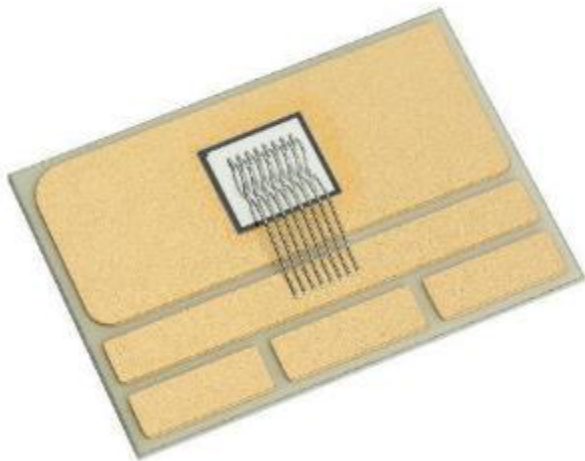
Pre-Drying

Hot Die
Placement

Pressure
Sintering

Applications

High Power Packages



Properties

Workable Surface

CTE

ppm/K

Thermal
Conductivity

W/mK

ASP043-04

Ag, Au

19

> 200

PE338

Ag, Au

Cu

19

> 200

PE338 F1510

Ag, Au

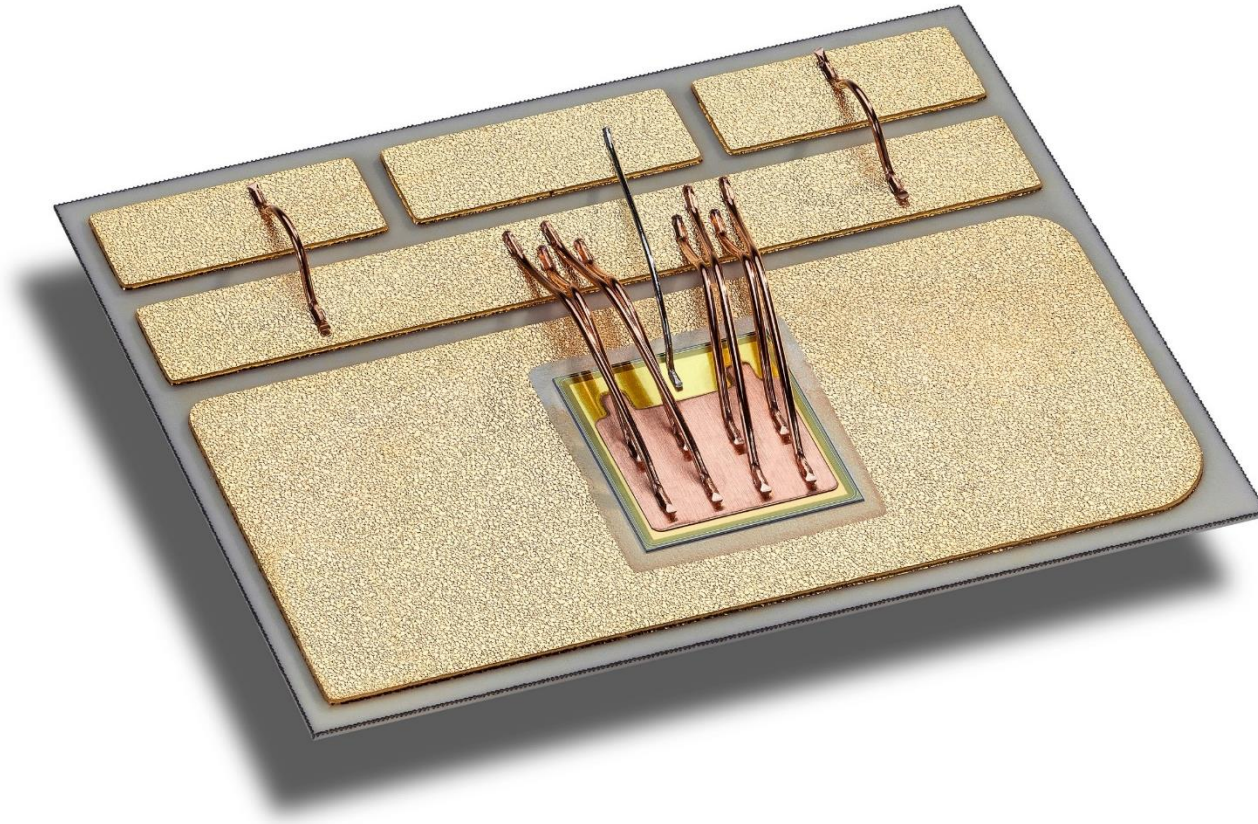
Cu

15

> 200

DIE TOP SYSTEM[®]

Get the most out of your Power Module



Key benefits

Die protection to enable Cu wire bonding with high yield

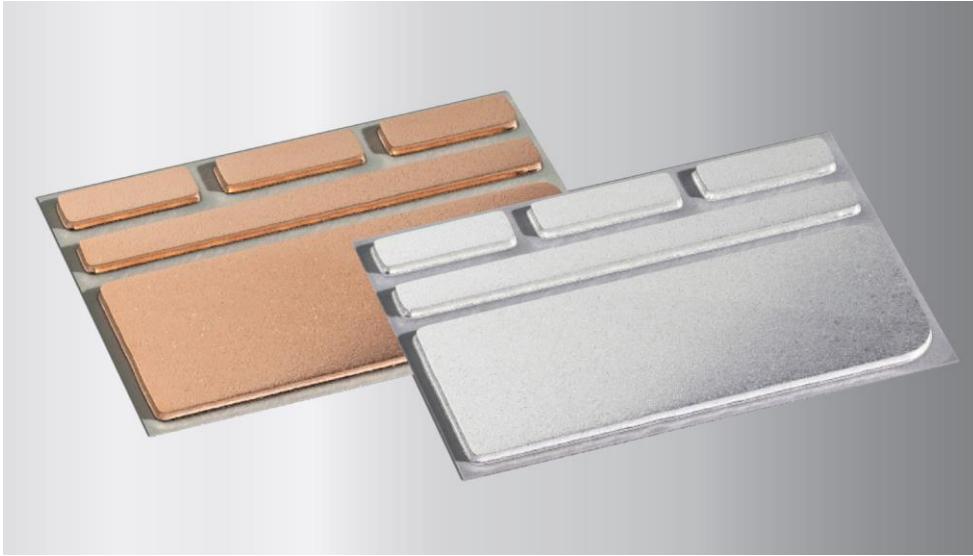
Best Performances

- Die current capability increases >50% vs. aluminum wire
- Significantly longer lifetime vs. solder die attach and Al-wire on system level
- Enables higher junction temperatures of more than 200°C
- Significant reduction of power derating or reduction of chip size

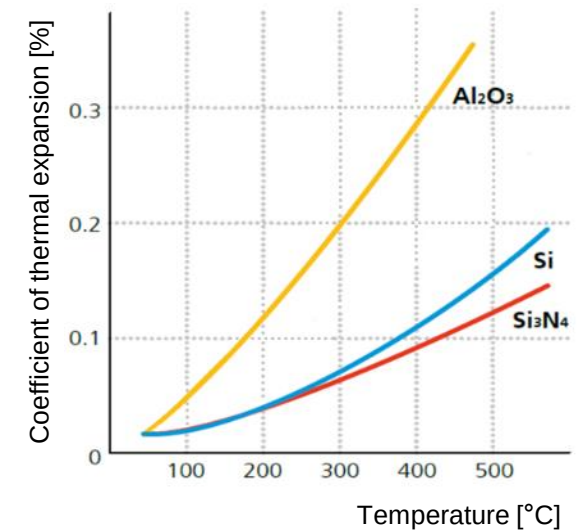
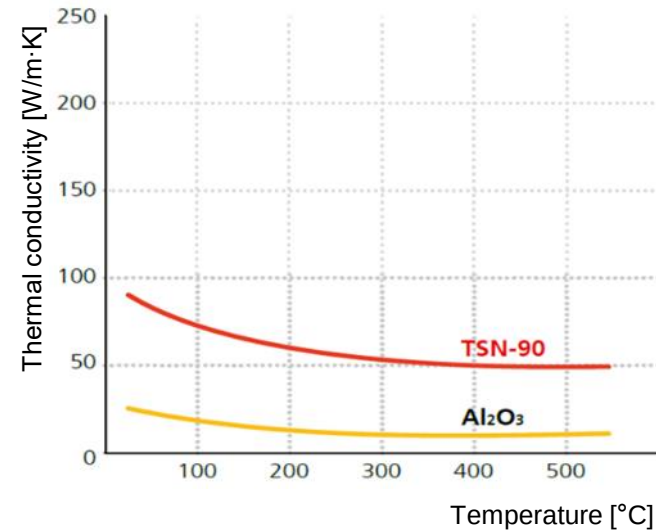
[®] Trademark registered in EU, JP

Picture: substrate layout by courtesy of Fraunhofer IISBs

Si_3N_4 AMB COMES WITH ESSENTIAL TECHNICAL ADVANTAGES VS. Al_2O_3



*Graphic: layout by courtesy of Fraunhofer IISB



- 5 times better thermal conductivity for excellent heat dissipation
- By factor of 3 reduced thermal expansion ideally matching semiconductor materials and resulting in low thermo-mechanical stress
- 50 times better reliability proven in thermal shock tests
- 3 times thicker copper layers for increased current capability

heat dissipation

reliability

current carrying
capability

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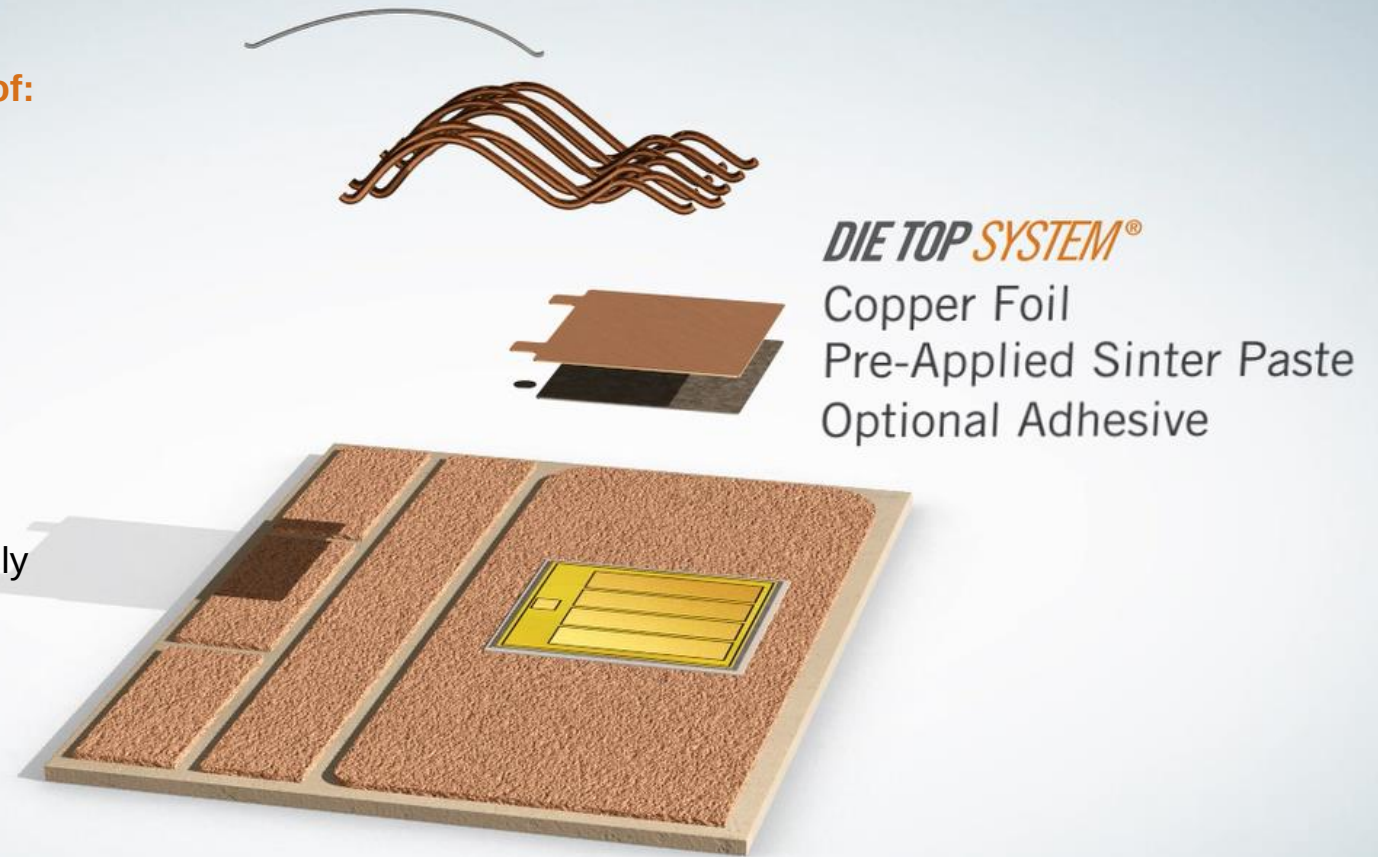
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The Die Top System (DTS®) is a Material System consisting of:

- › Copper foil with functional surfaces
- › Pre-applied sinter paste
- › Optional adhesive for DTS® fixation prior to sintering
- › Matched copper bonding wires

Reduce production complexity, optimize quality and yields:

- › Pre-applied sinter paste & adhesive dot to simplify the assembly
- › One step sintering process of the die and the die top system
- › Die Fixation System to prevent relative movement to the die prior to sintering
- › Functional surfaces optimized for sintering on the die (under side) and for bonding with Cu wire (upper side)



PRINTING PROCESS VARIABLES – INFLUENCE TO SINTER RESULT

The printing quality of sinter paste influence the final sinter result in terms of:

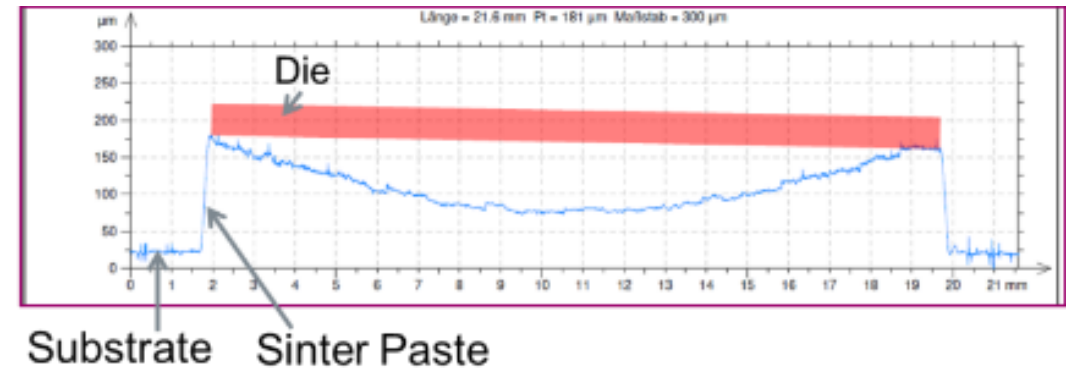
- mechanical strength
- reliability
- electrical resistance
- thermal conductivity

Good printing



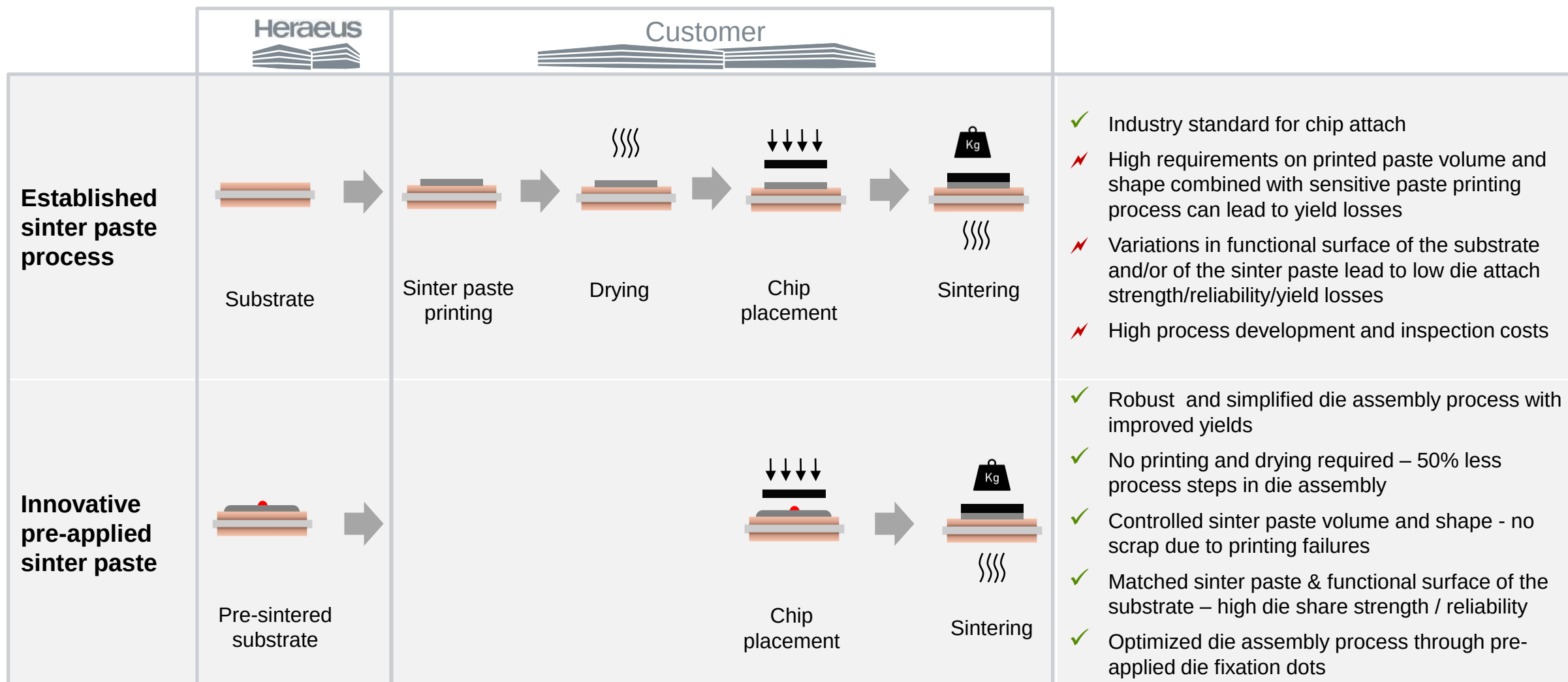
controlled printed volume and the right shape of the sinter paste are required to get optimal die attach performance

Bad printing



example: not perfect shape of printed paste leads to air gap under the die and consequently to major reliability issues

PRE-SINTERING SERVICE → SIMPLIFIED AND HIGH YIELD CHIP ATTACH



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Si₃N₄ AMB : COOPERATION WITH TOSHIBA MATERIALS FOR QUICKER TIME TO MARKET

Cooperation – boundary conditions

- › Both companies will jointly pursue the market launch
- › Both companies gain to better supply the market by combining their expertise in production, technology for the bonding of metal and ceramics, structuring, finalizing, and sales.
- › Both companies will use their established customer relations and serve their customers independently.



Competitive advantage for the customer

- › Toshiba is the market leader in the production of Si₃N₄ ceramics
- › Contractual assigned volumes of unstructured bond ware guarantees reliable and scalable supply
- › Most advanced back end manufacturing equipment is key for high yield production

ENGINEERING SERVICES TO ACCELERATE THE INTRODUCTION OF NEW DEVELOPMENTS IN PRODUCTION

ENGINEERING SERVICES



Simulation

- › Thermal simulation
- › Thermo-mechanical stress simulation
- › Lifetime prediction



Material Analysis

- › Fatigue analysis
- › Root cause analysis



Process Optimization

- › Parameter definition
- › Yield optimization



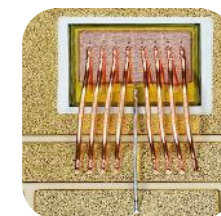
Prototype Design

- › Electrical design
- › Mechanical design



Prototype Assembly

- › Power modules
- › LED modules
- › Documentation, Traceability

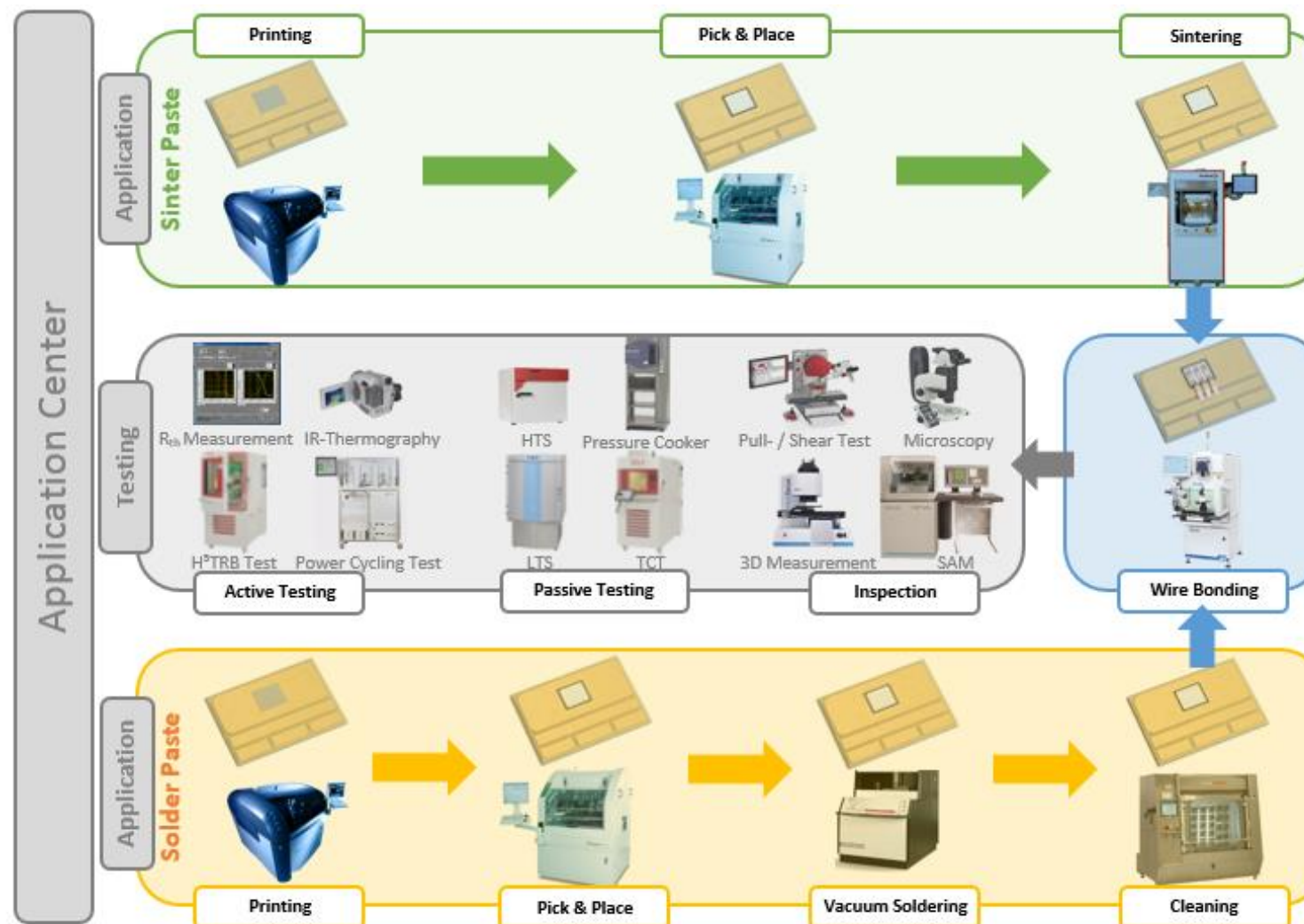


Testing and Qualification

- › Environmental tests
- › Thermal cycling tests
- › Active cycling tests



APPLICATION CENTER FOR POWER ELECTRONICS – CAPABILITIES



PROTOTYPING SERVICE SINTERING / DTS PROVIDED BY HET

Professional equipment

PINK SIN 200+

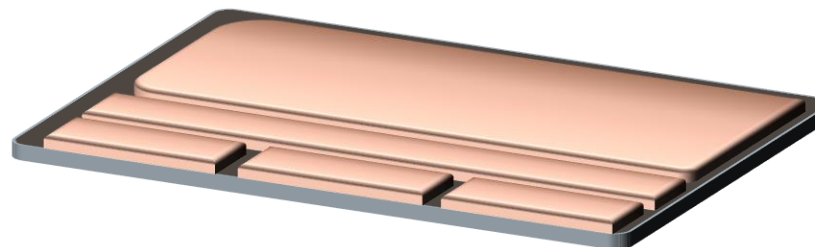
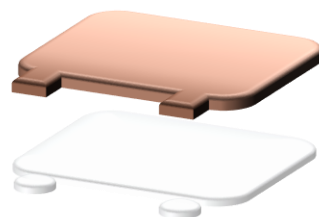


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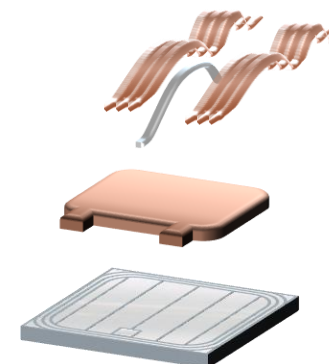


Boschman
Sinterstar

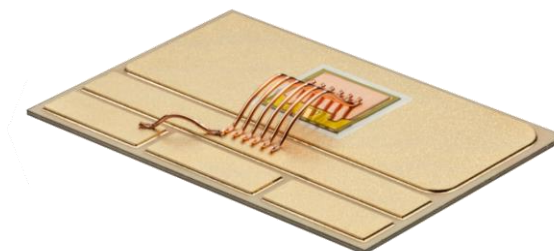
Innovative products



Professional service at HET



Satisfied customer

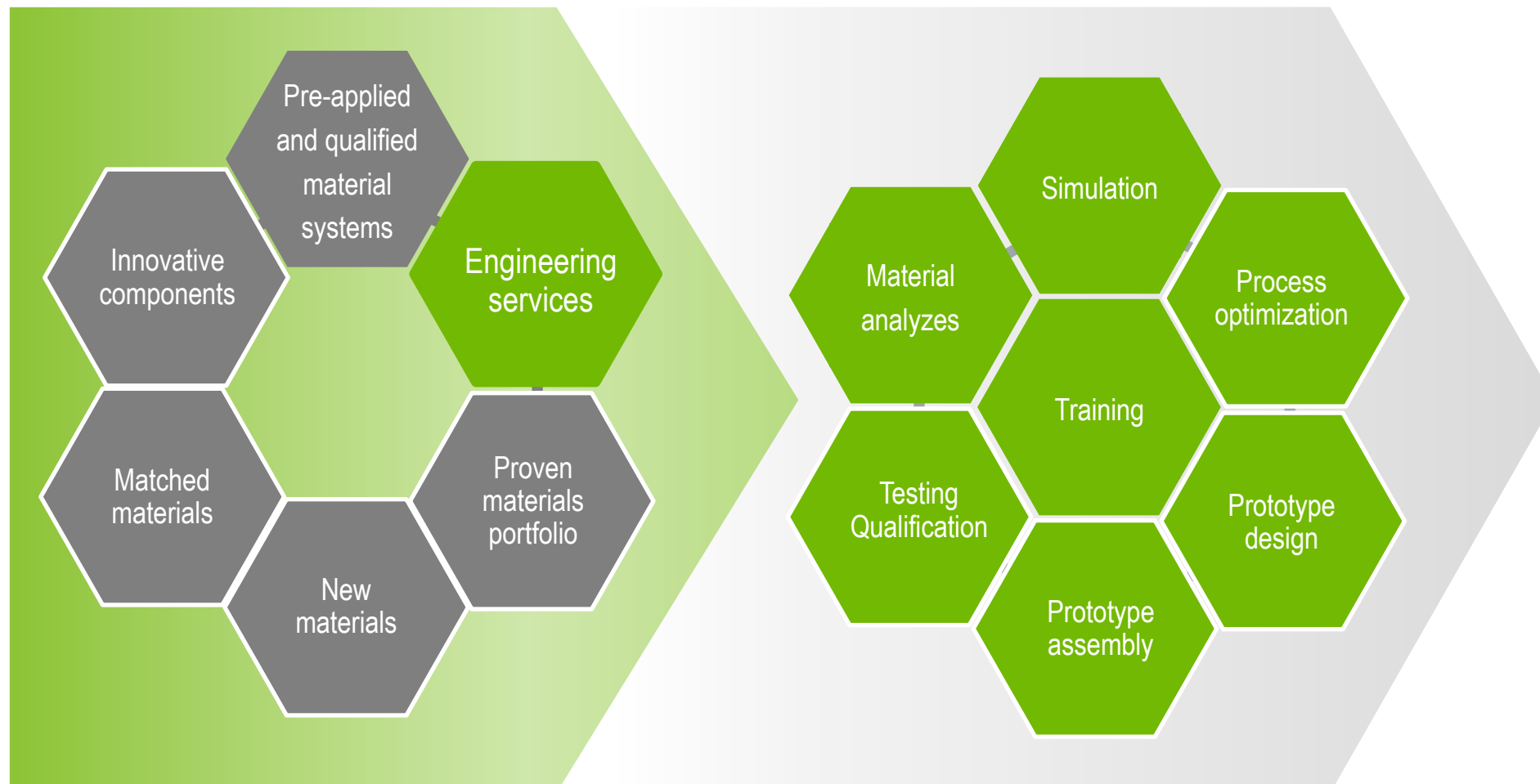


SCOPE OF ENGINEERING SERVICES

OUR SOLUTIONS

OUR ENGINEERING SERVICES

YOUR BENEFITS



Thank you for your attention

Dr. Aarief Syed-Khaja

Engineering Services & Product Management

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