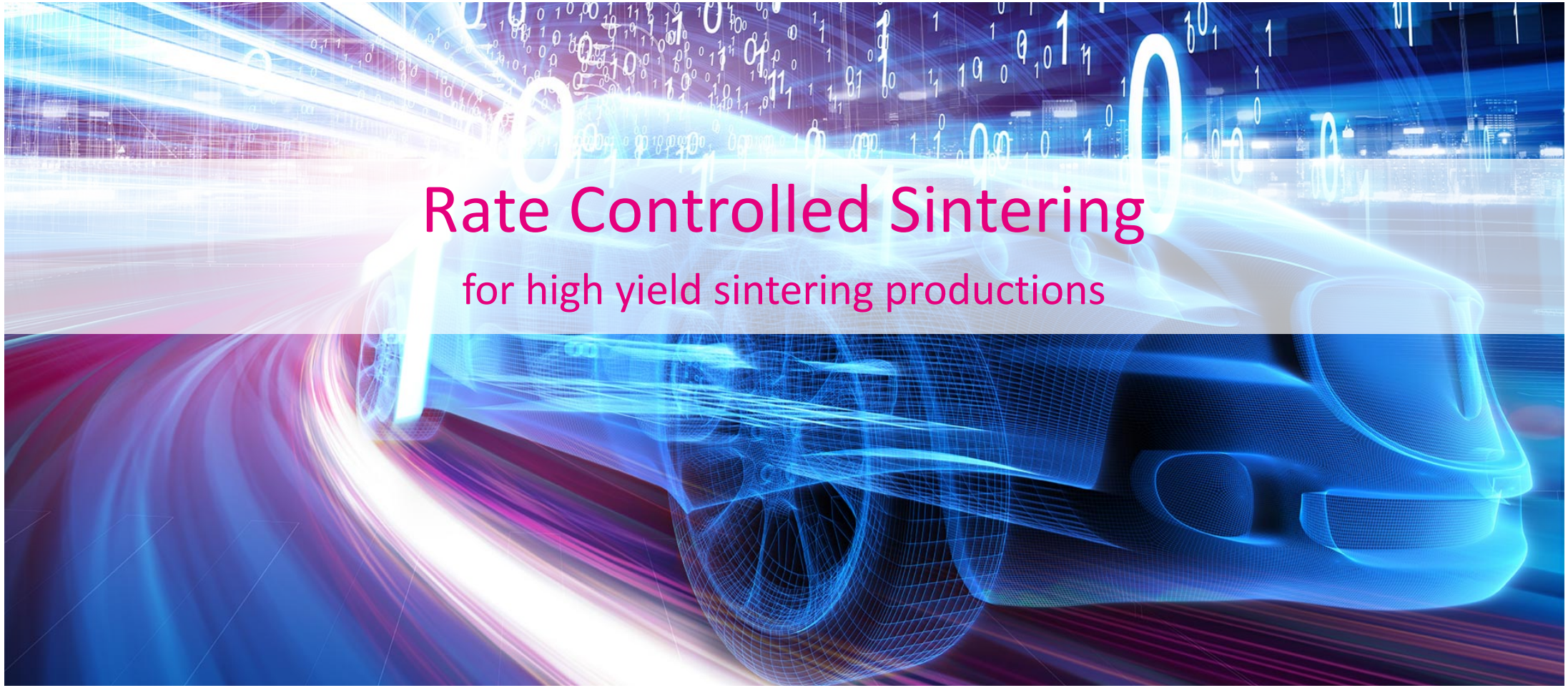


Rate Controlled Sintering

for high yield sintering productions

Thomas Krebs

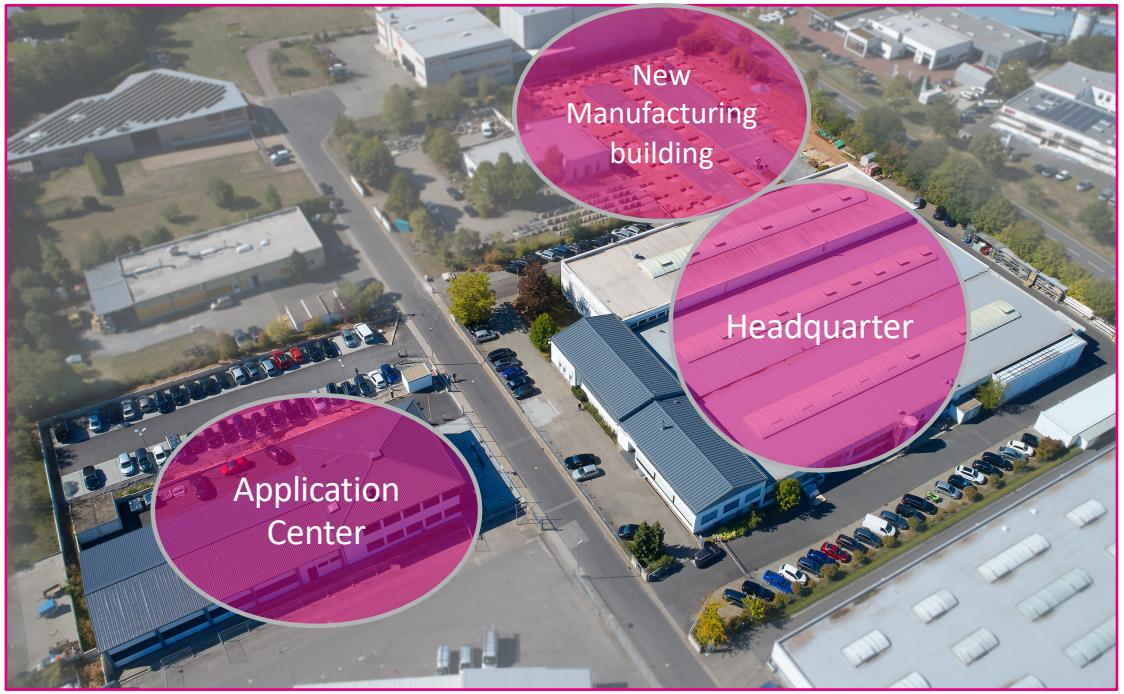
Content

- About PINK GmbH Thermosysteme
- PINK Sintering Systems
- Sintering - Motivation and Challenges
  - Motivation for sintering
  - Critical aspects
- Rate Controlled Sintering
  - Stages of Sintering
  - Concept of Rate Controlled Sintering
  - Test Results
- Summery

About PINK

Facts about PINK GmbH Thermosysteme

- Founded by Friedrich Pink in 1979
- Managed by his daughter Andrea Althaus
- Located in Wertheim am Main (near Frankfurt)
- Currently about 150 employees
- Four fields of competence:
  - Soldering Technology
  - Sintering Technology
  - Drying Technology
  - Plasma Technology
- Affiliated company: PINK GmbH Vakuumtechnik (since 1986)
- International subsidiary: PINK Japan K.K. (since 2015)
  PINK North America (since 2018)



Application at PINK

The core mission of customer application at Pink is caring about technical customer needs and questions with regards to soldering and sintering of power semiconductor packages. This includes training of customers, offering seminars as well as general and customer specific process development.

Range of Services

- Customer demonstrations
- Feasibility studies
- Process development and support
- Process training
- Research- and development work

Figure 1: New application & training center, opened summer 2018.

PINK Sintering Systems

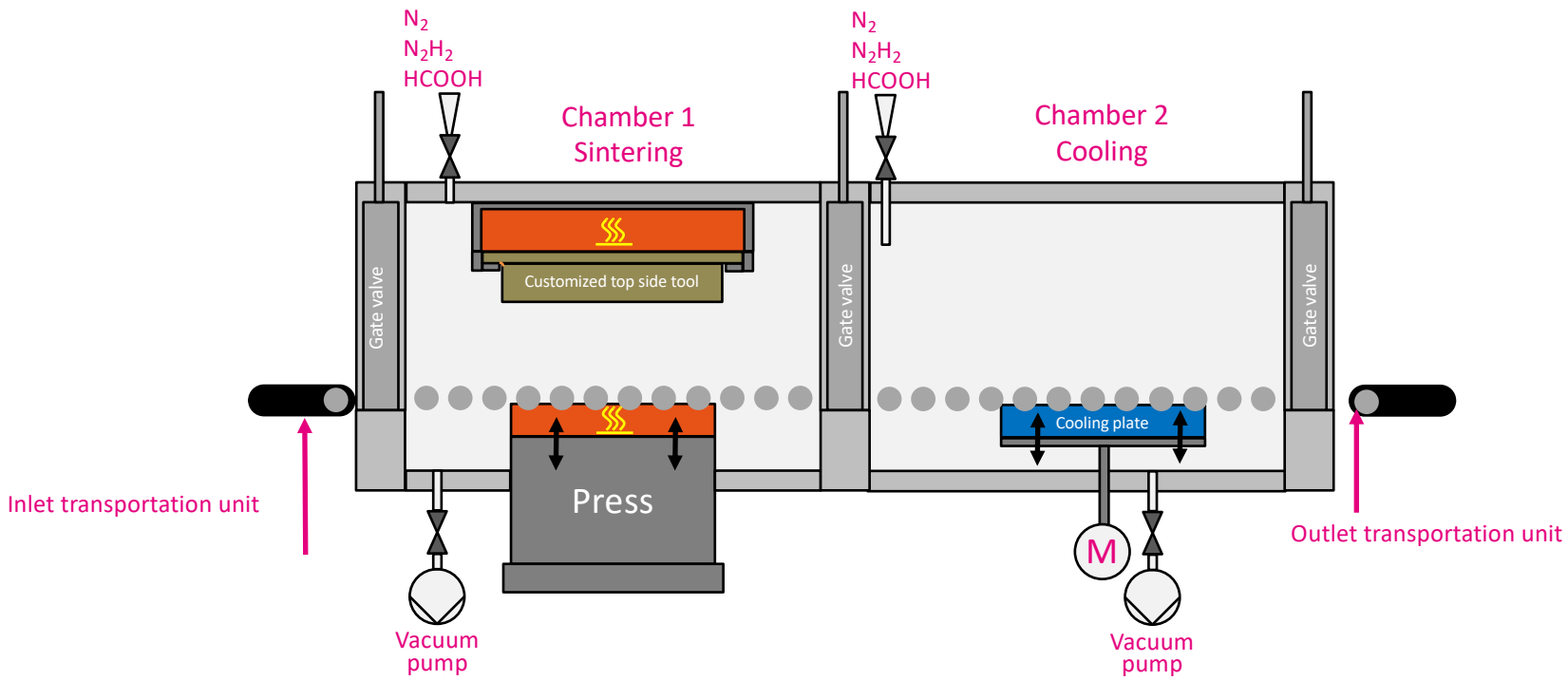
PINK Sintering Systems

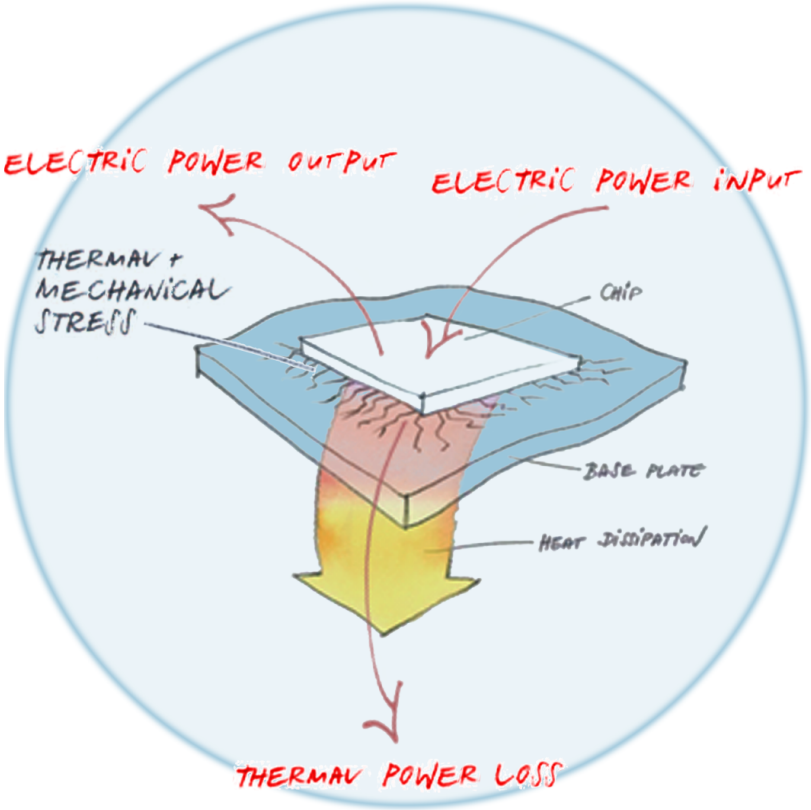
- Pressing force: up to **2.000 kN** (200 tons)
- Top and bottom side stamp can be pre-heated up to **350 °C**
- Exchangeable press tools
- Continuous high resolution force- and distance measurements enable closed-loop control
- Able to adapt press position to compensate for smallest drifts in product geometry, in order to stabilize applied pressure , e.g.
  - Height rise during heating through thermal expansion
  - Height loss during sinter layer compression
- **Vacuum Chamber**

  ➔ Exact control of gas atmosphere (N_2, N_2/O_2, N_2/H_2, HCOOH)

PiNK®

Sintering system SIN200: Operating principle





Sintering – Motivation and Challenges

PiNK®

Motivation for Sintering

Material properties	Ag -sinter	SnAg3.5 solder
Melting point [°C]	961	221
Thermal conductivity [W/m*K]	250[1]	60
Electrical conductivity [10^6 S/m]	41	8
CTE [10^{-6} /K]	19	28

[1]source: VSCM Technologie-Forum, Fraunhofer IISB
[2]exact value depending on silver flake size and process settings

- Higher temperature capability of silver sintering due to higher melting point
- Lower ΔT of silver sintering due to better thermal conductivity
- Lower ΔT of silver sintering due to better electrical conductivity
- Lower CTE mismatch of Ag to Si and therefore lower thermo-mechanical stress (=higher lifetime of silver sintering)

Increase in Power Density + Life Time

Lower System Costs

PiNK®

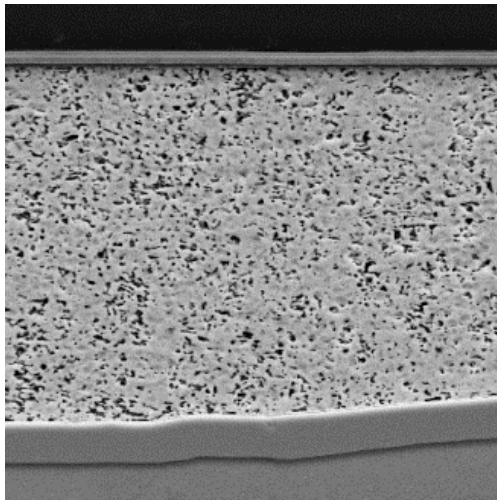
Critical Aspects

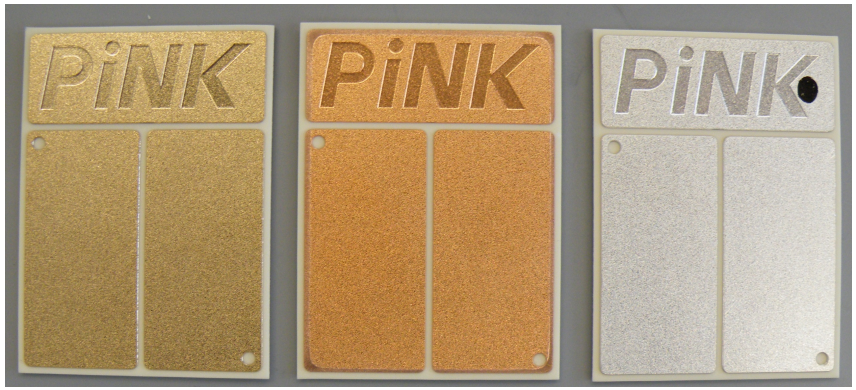
- Sintering process causes higher costs compared to soft soldering, because
  - Sinter pastes are more expensive then soldering pastes
  - New equipment is necessary: drying, pick & place, sintering press, quality inspection
  - Different process know how needed in design and manufacturing
  - New power module design + qualification
- Considering the power electronic system will gain cost reduction
  - Reduction of semiconductor area at same power (amps per Euro)
  - Increase of maximum junction-temperature
  - Reduction of cooling effort, design space and weight
  - Increase of lifetime and reliability
  - Reliable manufacturing process supplying high yield and quality

Critical Aspects

- Sintering require oxide free metal interfaces
  - Sinter materials are porous after processing
  - Removal of residues after processing inside of pores not possible

  ➔ Sinter materials are free of resins and activators
    - No removal of oxides from surface by sinter materials
  - Clean and oxide free surfaces are required
  - NiAu, Ag or clean Cu surface finishes to be used on DCB

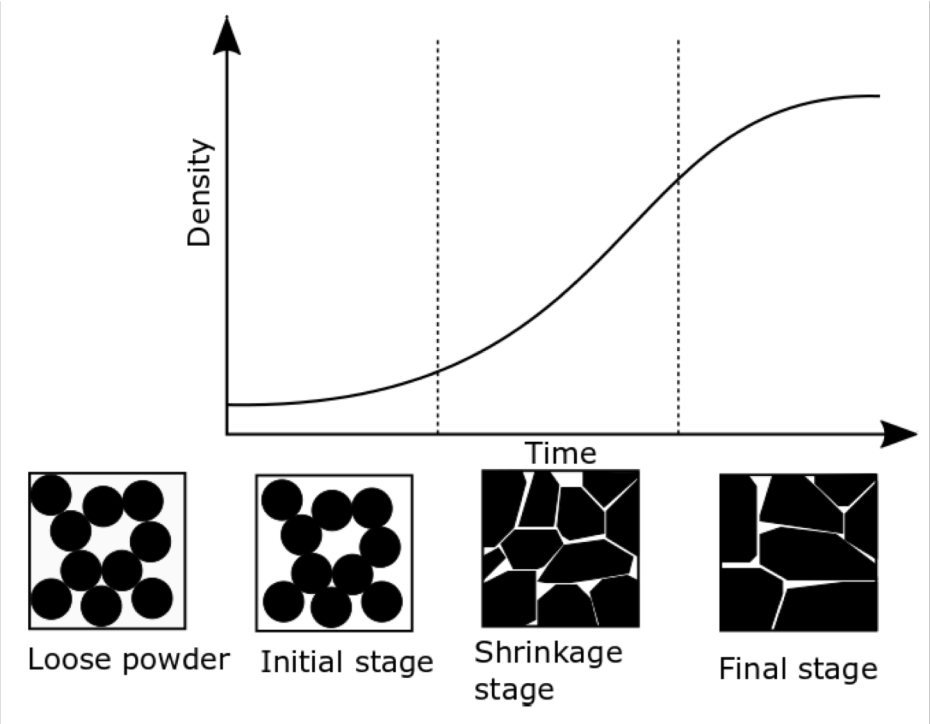




PiNK®

Use of vacuum chamber for sintering processes

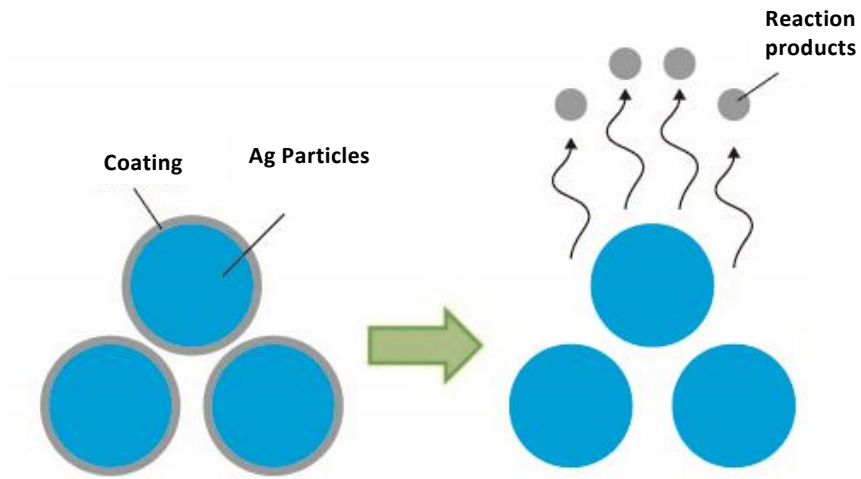
- Sintering under configurable oxygen level reduces surface oxidization
- Application of reductive atmosphere after sintering removes oxide layers on substrate and chip surface
  - No precious metal surface finish needed
  - No additional product cleaning necessary
  - Bare copper DBCs save material costs
  - Copper layer on top side of chip and substrate allow direct copper wire bonding
- Contamination with sulfur can be prevented

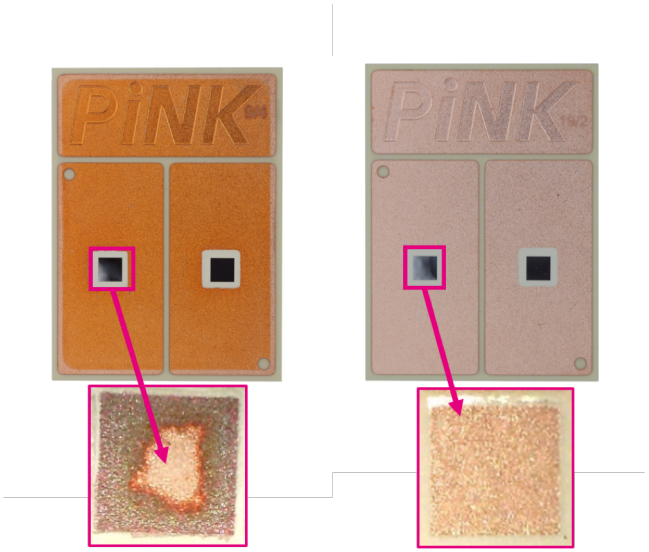


Rate Controlled Sintering

Stages of Sintering

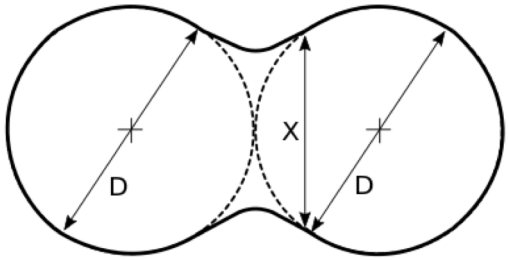
- Burning of coating on powder surface
  - Oxygen required to remove coating and start sintering reaction
  - Tight control of O_2 level required, if non precious metals are used as substrate surface





Stages of Sintering

- Initial stage
  - Low temperature and pressure ➔ low energy phase
  - Surface diffusion & evaporation-condensation mechanism
  - ➔ no densification
  - ➔ most processes optimized to shorten initial stage

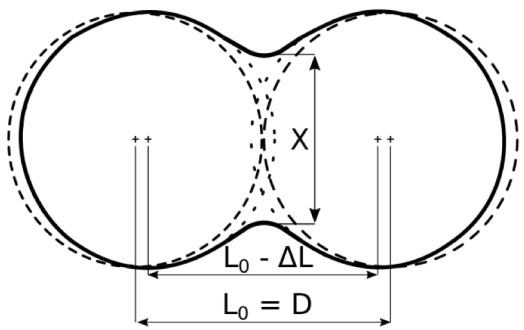


Stages of Sintering

- Shrinkage stage
  - Increase of temperature and pressure during the processing
  - grain boundary and volume diffusion resulting in approximation of particles

  ➔ reduction of number and size of pores
    - porous network collapsing into single closed pores

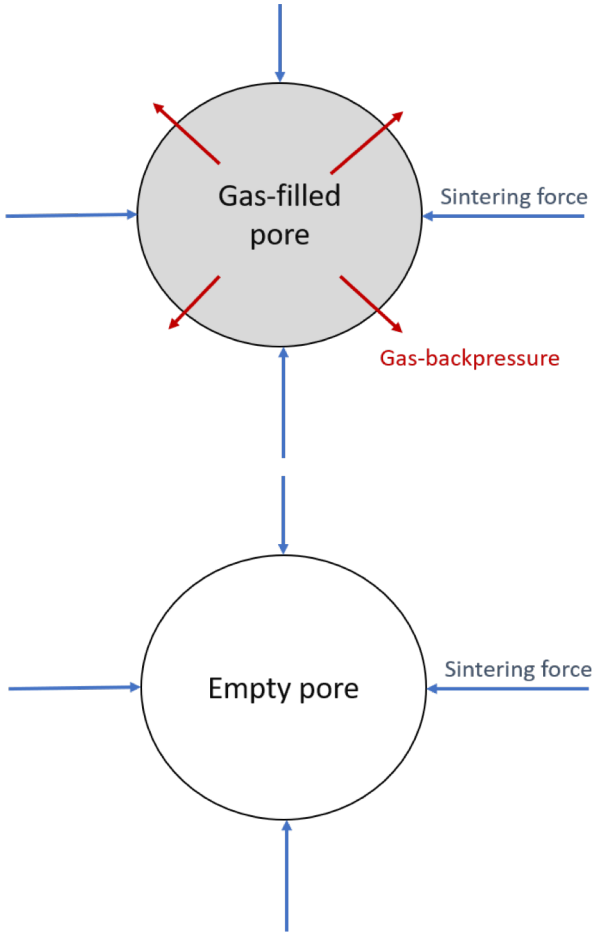
  ➔ densification of sinter layer



Stages of Sintering

- Final stage
  - reduction of grain boundaries
  - Back pressure inside gas filled, closed pores in case of air or protective gas sintering

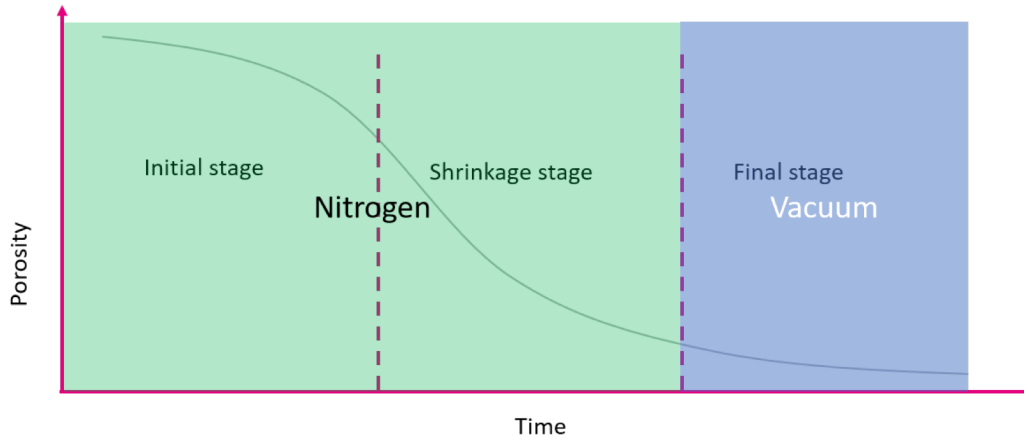
  ➔ Low gas pressure processes to reduce back pressure



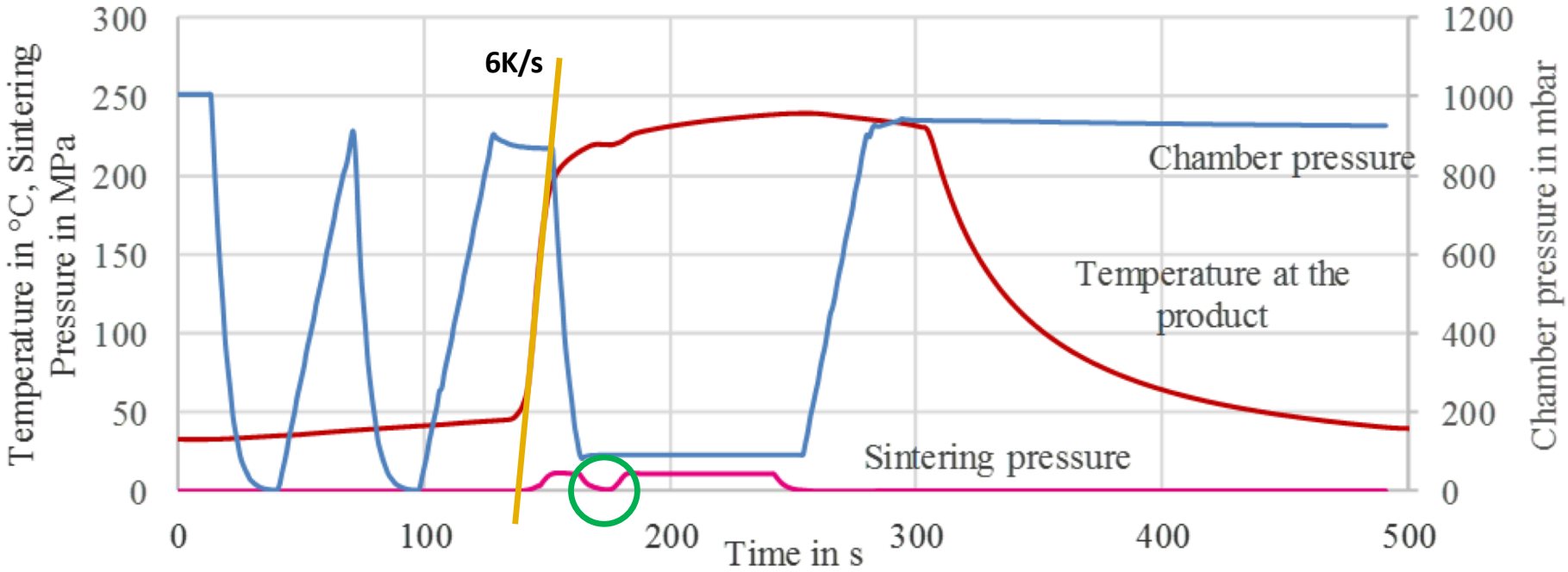
PiNK®

Concept of Rate Controlled Sintering (RCS)

- Control of critical parameter during the different sintering stages
  - Temperature
  - Time
  - Pressure
  - Atmosphere
- Controlled adjustment of material properties of sinter layer
- Minimize variation of properties of sinter layer

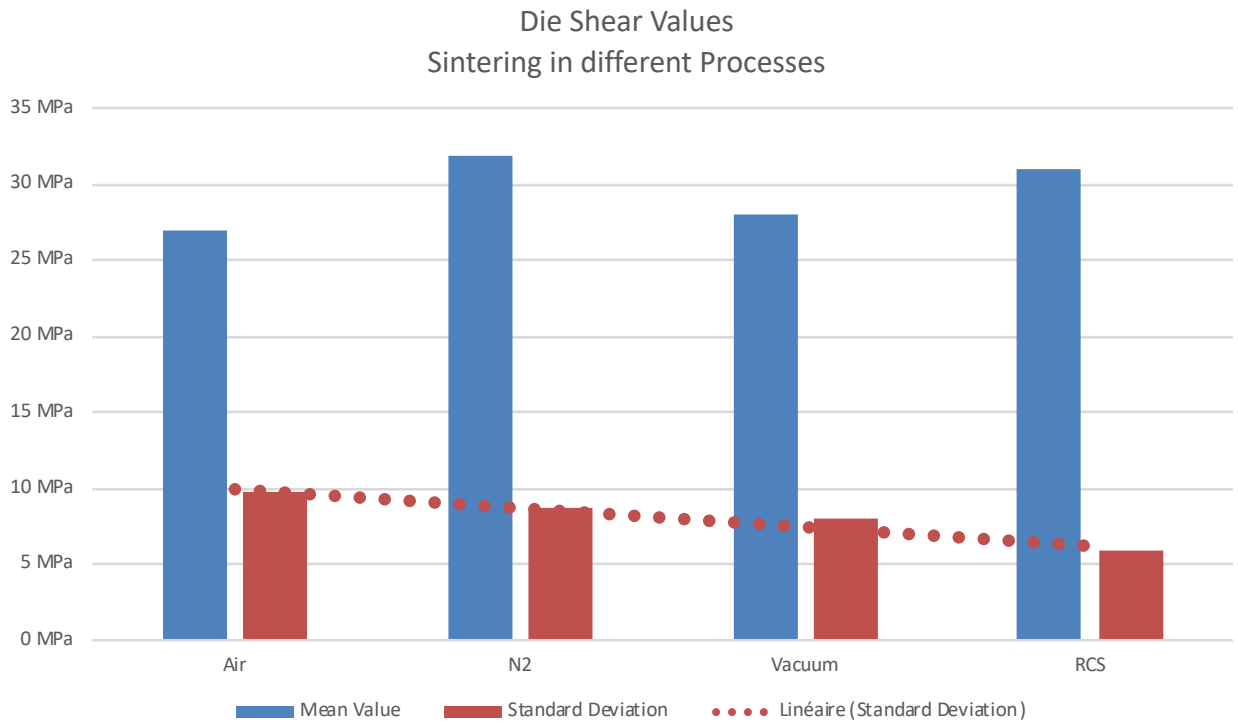


RCS Profile


6K/s
Temperature in °C, Sintering Pressure in MPa
300
250
200
150
100
50
0
1200
1000
800
600
400
200
0
Chamber pressure in mbar
Chamber pressure
Temperature at the product
Sintering pressure
0
100
200
300
400
500
Time in s

Test Results

- As test criteria die shear value was used to compare sintering results of different processes
  - Materials used
    - Heraeus Cu DCBs
    - 1x1mm dies, Ag backside metallization
    - Heraeus Ag sinter paste LTS 338
  - Die shear value increases by 15% comparing sintering in air and RCS
  - Reduction of standard deviation by 40% comparing sintering in air and RCS
- Improvement based on
  - Different sintering atmosphere
    - Lower level of 02 support bonding (shear value of sintering in air vs. Sintering in N2/RCS)
    - Reduction of back pressure during sintering by use of vacuum (standard deviation of shear value sintering in Air vs. sintering in vacuum/RCS)



Summery

- RCS allowing better control of sintering process
  - Use of vacuum chamber allowing required control of sintering atmosphere
  - Use of controlled atmosphere to reach
    - higher shear values
    - lower standard deviation
  - Design of properties sinter layer generally possible
    - Adjustment of porosity to adjust e.g. (initial) Youngs modulus according to package design
  - Shorten of sintering time based on density requirement / die shear requirement of sinter layer
  - RCS increases the robustness of sintering process ➔ decrease of process costs / quality costs
- Further improvement of process parameter possible
  - Keep sinter pressure during vacuuming of process chamber
  - Increase the slope of heating to reduce effect of surface diffusion

Contact
PINK GmbH Thermosysteme
Thomas Krebs
Head of Application
Am Kessler 6
97877 Wertheim
Germany
Tel.: +49 (0)9342 / 919 - 0
eMail: tkrebs@pink.de
www.pink.de