Vacuum-assisted Sintering in Mass Production: Challenges and Solutions
General information

- Founded by Friedrich Pink in 1979
- Managed by his daughter Andrea Althaus
- Located in Wertheim am Main (near Frankfurt)
- Currently 130 employees
- Four fields of competence:
  - Soldering Technology
  - Sintering Technology
  - Drying Technology
  - Plasma Technology
- All product ranges depend on vacuum technology
- Affiliated company: PINK GmbH Vakuumtechnik (since 1986)
- International subsidiary: PINK Japan K.K. (since 2015)
- New application and training center: Opening 2018
Vacuum-assisted Sintering

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1. Motivation for sintering

- Sintering causes higher costs compared to soft soldering
  - Sinter pastes are more expensive than soldering pastes
  - New equipment is necessary: drying, pick & place, sintering press, quality inspection
  - New power module design + qualification

- Cost reduction is only possible for the complete power electronic system
  - 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

- It is only worthwhile to invest in sintering, if the complete system is considered!
1. Motivation for vacuum-assisted sintering

- Vacuum technology / controlled atmospheres ensure a high process stability and yield
  - Controlled removal of paste residues
  - No oxidation of surfaces
  - No contamination with sulfur
  - Controlled moisture within the chamber

- Cost reduction is only possible for the complete assembly line
  - Higher yield at the sintering process compared to standard processes on air
  - Lower deviation of reliability properties (e.g. shear force, porosity)
  - Higher yield at following processes (e.g. wire bonding or molding)

- It is only worthwhile to invest in the vacuum technology, if the complete line, process stability and yield is considered!
2. Case study: die shear strength after sintering with different atmospheres

- Material used
  - Silver sinter paste for direct contact to copper
  - 4 mm x 4 mm chips
  - DBC $\text{Al}_2\text{O}_3$ ceramic

- Sintering parameters
  - Atmospheres: air, $\text{N}_2$ and vacuum
  - 12 samples per atmosphere
  - 10 MPa pressure
  - 2 min and 250 °C

- Shear tests for every group
2. Case study: die shear strength after sintering with different atmospheres

Shear values of sintered dies at 10 MPa

- Under air showed a high standard deviation and a low mean
- Under vacuum showed a low standard deviation and a significantly higher mean
- Under N₂ showed a low standard deviation and the highest mean
2. Case study: root-cause of lower die shear values on air

Sintering on bare copper under air

- Oxygen penetrates through the sinter layer
- Oxidization of Cu surfaces

Explanation for high deviation for shear values under air

- Depending on the oxidation penetration
- Deviation of printing and pick&place processes

Explanation for the lower shear values

- Oxygen penetrates through the paste to DBC surface
- Less bonding strength due to Cu oxides

Figure 1: DBC Cu surface after die shear – sintering under air

Figure 2: DBC Cu surface after die shear - sintering under N₂
2. Case study: Influence of sintering parameters under different atmospheres

- Variation of sintering parameters
  - Temperature: 230 °C, 250 °C, 270 °C
  - Pressure: 10 MPa, 20 MPa, 30 MPa
  - Time: 60s, 120s, 180s
  - Atmosphere: N\textsubscript{2}, vacuum

- For N\textsubscript{2} sintering
  - Flooding with N\textsubscript{2} to 950 mbar again
  - Oxygen content: 50-100 ppm

- For vacuum sintering
  - Chamber pressure at 5 mbar
2. Case study: Influence of sintering parameters under different atmospheres

- Results of shear values under N$_2$ sintering
  - Temperature and time have a huge impact
  - Pressure has a low impact
2. Case study: Influence of sintering parameters under different atmospheres

- Results of shear values under vacuum sintering
  - Temperature still has a huge impact
  - Pressure has a higher impact
  - Time has no impact
2. Case study: Influence of sintering parameters under different atmospheres

Root-cause for sintering results under vacuum

- For this study a atmospheric pressure of 5 mbar was used
- Vacuum affects two kinds of mechanisms, that either improve or impede the sintering reaction

- Impeding the sintering reaction:
  - Vapor-condensation

- Improving the sintering reaction:
  - Grain boundary diffusion
  - Volume diffusion
  - Plastic deformation
  - Creep deformation
2. Conclusion of case study

- Sintering under controlled atmospheres
  - Can significantly increase shear values
  - Can significantly lower standard deviation with the production
  - Can improve the stability of the following production processes
- Vacuum has to be used at the right pressure and time to achieve good results
- Vacuum technology achieves highest occupational health and safety conditions
3. Challenges of vacuum-assisted sintering in mass production

To get economically solutions with vacuum-assisted soldering the production must fulfil many requirement:

- Many devices per sintering run
- Short cycle time
- Stable and safe process
- Highest yield
- Low maintenance downtime
PINK solutions for vacuum-assisted sintering:
4. Sintering system SIN200: All key facts for a successful mass production

To achieve a high throughput:
- Pressing force: up to 2,000 kN (200 tons)
- Top and bottom side stamp can be pre-heated up to 350 °C

To ensure highest yield and a reliable process:
- Exact control of inherent gas atmosphere (N₂, N₂/H₂, HCOOH)
- Continuous high resolution force- and distance measurements enable closed-loop control

To be flexible for different products and layouts
- Press tools are exchangeable and can be customized in all needs
- Standard sintering tool available with process area: ≤280 mm diameter (61575 mm²)
4. Sintering system SIN200: Modular design with flexible expandability

SIN200
stand-alone

SIN200+
Preheating module
Cooling module

SIN200+
Cooling module

SIN200+
Reduction module
Cooling module
4. Foil handling concepts: Pick&place

Before entering the machine:
Foil will be placed

After the sintering process:
Foil will be removed
4. Sintering system SIN200: Foil handling by pick&place

To ensure a stable process:
- Foil handling out of „hot zone“
- Constant foil temperature
- Separated foil handling and sintering process
- High occupational safety

To ensure highest throughput at lowest costs:
- Mounting/re-filling without downtime
- Efficiency: no waste of foil
- Foil can be re-used
- 100% traceability
4. Sintering system SIN200: Automation concepts for series production

- Fully automated handling
- Robot station incl. lift station + underfloor return
- Reloading from/to magazine by robot is possible
4. Sintering system SIN200: Software and visualization by PINK

- Fully developed and maintained In-house
- Customer specific functions and layout are possible
- Real-time indication of process parameters
- Create, adapt, save and organize recipes
- View live and trend data of all sensors
- Export diagrams to Excel
- Manual control of the whole machine
- Adapt machine parameters and settings
4. Example of silver sintering in series production: PINK and Infotech

- Reload-station: Magazine into carrier
- Pick&place with temperature and pressure IGBT + Diode
- Reload into PINK carrier
- Foil handling
- Pre-heating
- Sintering
- Cooling
- Foil handling
- Reload into magazine
5. Application by PINK

- Services
  - Customer demonstrations
  - Feasibility studies
  - Machine capability studies
  - Prototype assembly
  - Process development
  - Process training
  - Research- and development work

- Opening of the new application- and training center in a few weeks
5. PINK – your partner for continuous support for soldering applications

• **Before purchase order**
  – Consulting during the design phase
  – Development of a concept for series production
  – Design of experiments, assembly of samples and evaluation of throughput and quality
  – Analyzation and preparation of necessary machine modifications together with the customer

• **After purchase order**
  – Assembly of further samples for the next qualification phase
  – Characterization and reliability testing of sintering tools
  – Continuous improvement of soldering parameters and soldering jigs / fixtures

• **After delivery of customized soldering machine**
  – Fine tuning of the soldering process
  – Training of customers’ engineers and technicians
  – Continuous support by PINK application and service team
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