„FAST“ - Field Assisted Sintering Technology

Basics, State of the Art and Future Aspects

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FCT Systeme - company profile

Development of innovative concepts as well as design and construction of high-temperature furnaces for technical ceramics, powder metallurgy and solar industry.

from small lab – furnace to turn - key - production plant
EU-project “FAST”

“Field Assisted Sintering Technology for the Densification of Nanostructured Powders and Fabrication of Functionally Graded Materials”

FP5—“GROWTH”—Project N° GRD1-2001-40737

04 / 2002 – 03 / 2006
Spark Plasma Sintering (SPS) – Principle

- Power Supply System
- Vacuum chamber
- Hydraulic system
- dS/dt
- Temperature
- Vacuum, Ar / N₂ / H₂

**FAST SPS**
- Field
- Spark
- Assisted
- Plasma
- Sintering Technology
Pulse form modulation

High flexibility from pure DC to almost any pulse burst

Pulse duration $t_{\text{on}} = 1 \ldots 255$ ms
Pause duration $t_{\text{off}} = 0 \ldots 255$ ms
Pulse number $n = 1 \ldots 255$
Extra pause $t_{p} = 0 \ldots 255$ ms
Temperature difference ($\Delta T$) mould to sample

T(mould) – T(sample) = -210 °C

Controlled sample temperature < 4°C

Sample: TiN
Ø50 x 10 mm (97 % theo. density)
Sample temperature 1500°C
Simulation of FAST/SPS heating process

FEM calculation of experiment

FEM = Finite Element Method
Number of FCT FAST/SPS facilities worldwide
FAST/SPS series

60 kW - 250 kN

32 kW - 50 kN
FAST/SPS series

60 kW - 250 kN

180 kW - 1.250 kN
Semi-continuous FAST/SPS-system

Industrial Applications already in operation:

😊 Tungsten Carbide 175x150:  $t_{\text{eff}} = 35 \text{ min}$
😊 Noble Metal D200:  $t_{\text{eff}} = 20 \text{ min}$
😊 Chromium D60:  $t_{\text{eff}} = 10 \text{ min}$
😊 Ti / Al D100:  $t_{\text{eff}} = 4 \text{ min}$

360 kW - 2.500 kN
Important material properties

Pressing tool parts

- Electrical conductivity
- Thermal conductivity
- Thermal expansion
- Bending strength
- Fracture toughness
- Creep resistance
- Hardness
- Wear resistance

= f (T) ?

Degree of sintering

(Density, microstructure, phase comp.)
Finite element simulation of FAST/SPS heating process

Temperature distribution in Ø200mm sample after heating to 2100 °C - 100K/min

Standard tool design
\[ \Delta T > 250K \]

Optimized tool design
\[ \Delta T < 70K \]
SPS cycle of binderless WC using the HP D 250

Sample: sputter target (Ø200 x 13 mm)

Density: 15.51 g/cm³ (99.3% th. d.)

60 min

Spring School, Darmstadt March 2011
SPS process of a Al/Si alloy; using HP D 250

Sample: piston, pre-shaped (dia. 82 x 25 mm)

Density: 2.85 g/cm³, >99% th.D.

PWS = constant

90 sec.

Goal: 60 sec. (FAST²)
Samples made of different materials by SPS
6-fold SPS-mold Ø63x34 Cr-cathodes
FAST/SPS Hybrid – technology for sintering of large parts made from electroconductive powders
FAST\Hybrid system HHPD 600
(under construction by FCT Systeme GmbH)

1000 kW - 6.000 kN
**VISION: Fully automatic powder press**

Producing parts, which are net shaped and readily sintered
High speed FAST/SPS – dry press technology

- Cycle time: 10 – 30 sec / pc
- Pressing force: 200 kN
- Dimension: 1 … 5 cm²
- Fully automatic operation
Typical PIM – part of FAST-Sint®
### FAST/SPS material examples

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals:</td>
<td>W, Mo, Cr, Ru, Si, Cu, Cu (+W / Cr)</td>
</tr>
<tr>
<td>Intermetallics:</td>
<td>TiAl, Ni$_3$Al, PbTe, SmCo$_5$</td>
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<tr>
<td>Carbides:</td>
<td>WC, B$_4$C, SiC, TiC, ZrC</td>
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<tr>
<td>Nitrides:</td>
<td>AlN, TiN, Si$_3$N$_4$ (+TiN), hBN (+TiB$_2$)</td>
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<tr>
<td>MMC / CMC:</td>
<td>Al / Ti (+ SiC / Al$_2$O$_3$), Steel (+ TiC/N), Co / Cr / Pt (+ Oxides)</td>
</tr>
<tr>
<td>Cutting Tools:</td>
<td>WC-Co/Ni/Steel (+cBN, +Diam.), Al$_2$O$_3$-Ti(C,N)</td>
</tr>
<tr>
<td>Armor materials:</td>
<td>B$_4$C, SiC, ZrB$_2$, TiB$_2$, Al$_2$O$_3$ (+CNT)</td>
</tr>
<tr>
<td>Functional / Functionally Graded Materials („FGM“)</td>
<td></td>
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<tr>
<td>Transparent:</td>
<td>Spinel, Al$_2$O$_3$, Nanostructured Materials</td>
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</tbody>
</table>
Goal of FAST/SPS developments at FCT

- PRODUCTION COSTS
- MATERIAL PROPERTIES
- NEW POSSIBILITIES
Thank You For Your Attention

Merci De Votre Attention
Gracias por su Atención
Grazie per la vostra attenzione
Obrigado para sua atenção
Σας ευχαριστώ για την προσοχή σας
Danke für Ihre Aufmerksamkeit
Dank u voor uw aandacht
TEŞEKKÜR
谢谢您的注意

Спасибо за внимание
너의 주의를 위해 너를 감사하십시오
Tack för Uppmärksamheten
Takk for Oppmerksomheten