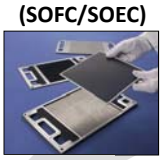
IEK-1 at a Glance – Research Topics

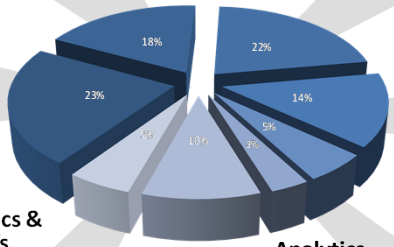
Head of Institute: H.P. Buchkremer (acting); R. Vaßen (vice)

Barrier Coatings
G. Mauer, D.E. Mack

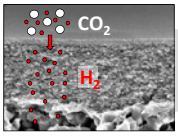
Solid Oxide Cells (SOFC/SOEC)
N.H. Menzler
F. Tietz



Total: 92 employees

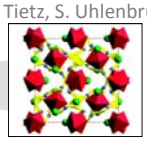


Gas Separation Membranes



W.A. Meulenberg
M. Bram

Solid-State Batteries
F. Tietz, S. Uhlenbruck



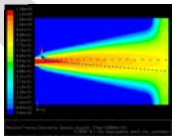
$Li_7La_3Zr_2O_{12}$ (electrolyte)

Special Topics & Spin-Offs
M. Bram

Workshop and Administration

Analytics
D. Sebold

Modelling
R. Mücke



Group M. Bram
„Powder metallurgy and material composites“

Energy related research (Helmholtz-Program Rational Energy Conversion):

- Gas separation in power plants: metal supported membranes and testing
- SOFC: Metal supported high temperature fuel cells

  (Sealing: mica, metal brazing)

  (New manufacturing technologies: roll coating, ink jet printing)
- New topic: Redox flow batteries (metal – metal oxide batteries)

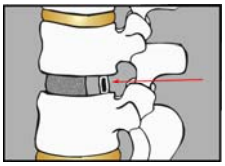
Spin-Offs:

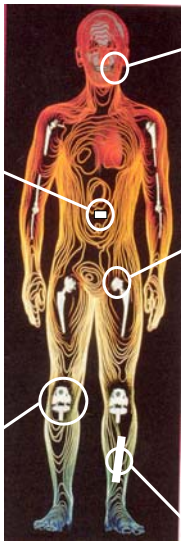
- Powder metallurgy of highly porous Ti
- Powder metallurgy of NiTi-shape memory alloys (MIM, HIP, Plamsa spraying)
- Hot isostatic pressing HIP (Transparent ceramics, metals,…)

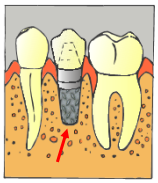
Established applications of metallic implants with functional porosity

Spine implants

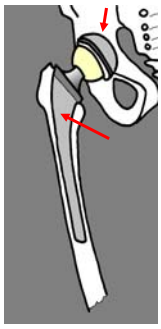
Replacement of vertebral disc







Dental implants

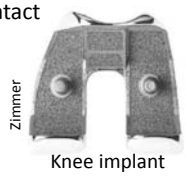


Hip implants:

- Acetabular Cup
- Porous coating on hip stem

Joint implants

Porous coating of surfaces in contact with bone



Knee implant

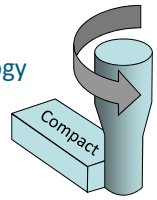
Repairing of bone defects

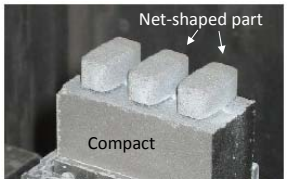
Net–shape manufacturing of P/M parts with space holder

JÜLICH FORSCHUNGSZENTRUM

Route A:
Green machining of compacts

- Development of processing technology
- Prototype acetabular cup
- Synthes: Spine cage (2007)

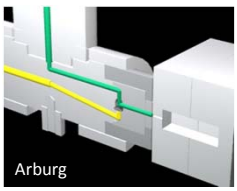




Machining of unsintered compacts (Green machining)

Route B:
2-Component-Metal Injection Moulding 2C-MIM

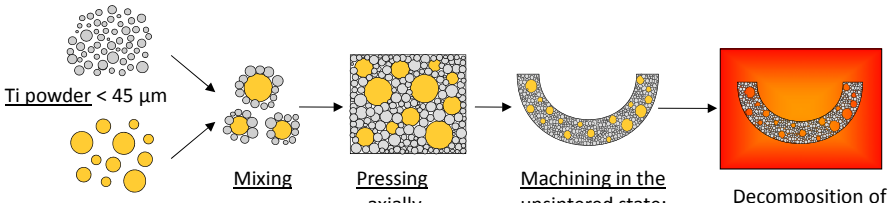
- Preliminary study
- Prototype spine cage



2 Component Metal Injection Moulding 2C-MIM

Route A:
Net shape manufacturing of porous titanium implants

Processing: Application of space holders in combination with green machining



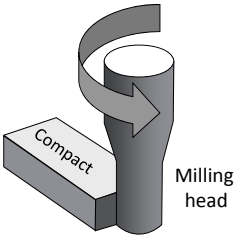
Ti powder < 45 µm

Space holder
e.g. $(NH_4)HCO_3$
Fractionising
by sieving:
125–250 µm,
355–500 µm

Mixing

Pressing
- axially
- isostatically

Machining in the unsintered state:
- Turning
- Milling



Decomposition of space holder:
(T ~ 100°C)

Sintering:
(T ca. 1300°C)

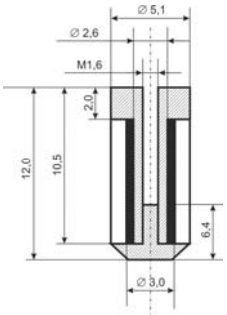
Laptev A. et al.,
Powder Met. 47 (2004) 85.

Bram M., et al., Adv. Eng. Mat. **2** (2000) 196.
Laptev A., et al., Powder Met. **47** (2004) 85.
Laptev A., et al., Powder Met. **48** (2005) 358.

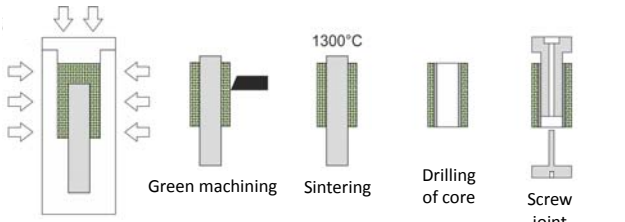
Patented technology:
Bram M., et al., (2002), DE 102 24 671 C1,
WO 2003 101 647, US 714 78 19.

Prototype of dental implant

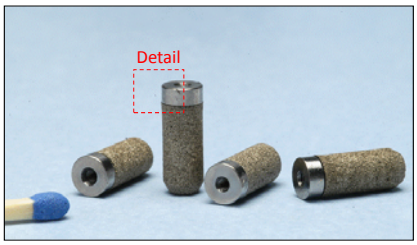
JÜLICH FORSCHUNGSZENTRUM

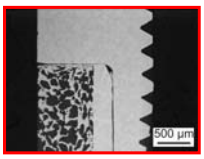


Manufacturing steps:



Isostatic pressing
Green machining
Sintering
Drilling of core
Screw joint





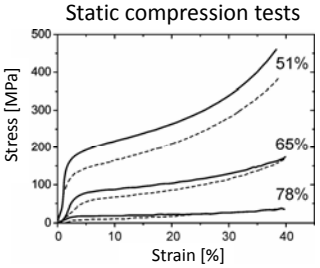
Schiefer H. et al., J. Mat. Sci: Mat. in Med. 20 (2009) 1763.

Arbeitsgruppe Martin Bram, Stand 26.03.2013

Characterisation of mechanical properties

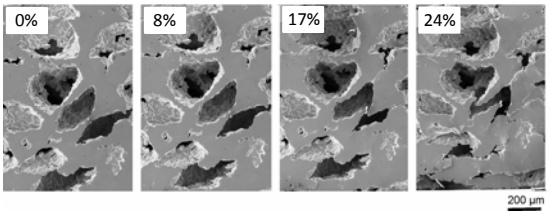
JÜLICH FORSCHUNGSZENTRUM

Static compression tests

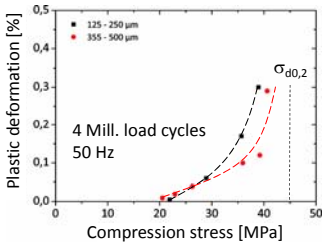


Singh R. et al., Acta Biomat. 6 (2010) 2342.

Deformation behaviour

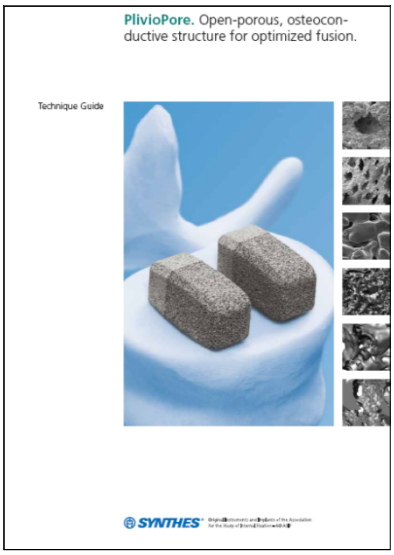


Cyclic fatigue ($\sigma < \sigma_{d0,2}$)



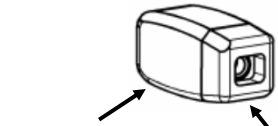
Schiefer H. et al., J. Mat. Sci: Mat. in Med. 20 (2009) 1763.

Licensing and introduction to the market: Spine implant developed by Synthes



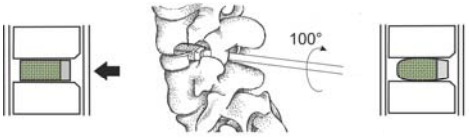
[Source: www.synthes.com]

Spine implant (cage) with gradient of porosity



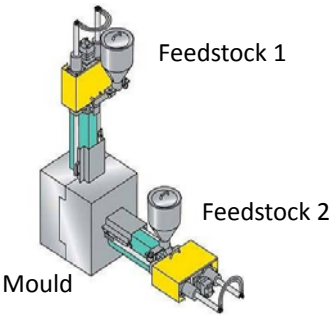
High porosity: Osseointegration

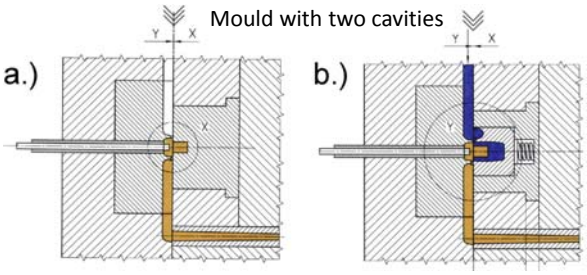
Low porosity: Screw thread for postioning of implant during surgery



Positioning during surgery: rotation
Clamping between adjacent bones

Route B:
2-component injection moulding 2C-MIM





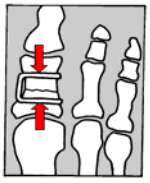
Advantages of 2C-MIM technology:

- Direct shaping
- Fully automated
- No machining required

Prototype of spine implant

A.P. Cysne Barbosa, M. Bram et al., Powder Injection Moulding Int. 6 (2012) 69 – 73.
A.P. Cysne Barbosa, M. Bram et al., Adv. Eng. Mat. (2013) accepted for publication.
Patent: H. Nelles, M. Bram, et al. (2002), DE 10248888, WO 2004039748, US 7351371.

Powder metallurgy of
NiTi shape memory alloys (SFB459)

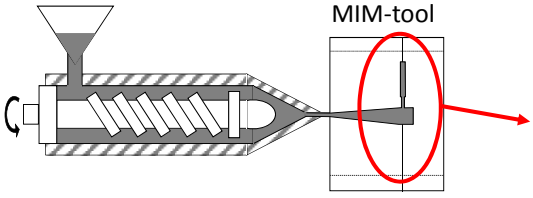


Biomedical staple

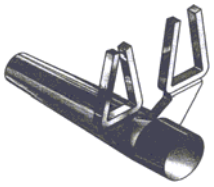
Aim:

- Demonstration of net-shape manufacturing of NiTi-parts by powder metallurgical processing
- Proof of function: staple for toe bone (One-way-effect)

Processing: Metal Injection Moulding MIM



Principle of MIM device



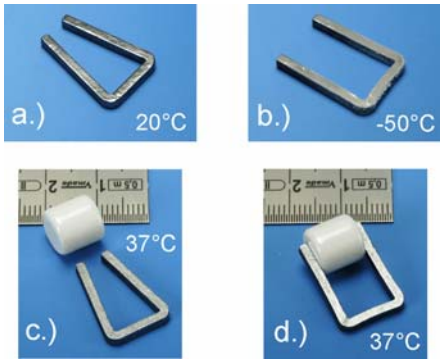
3D image of tool cavity

Prototype of net-shaped NiTi staple with shape memory

JÜLICH FORSCHUNGSZENTRUM

Permanent load on bone defects
by surpressing of shape recovery:
Support of bone healing

Demonstration of shape memory effect



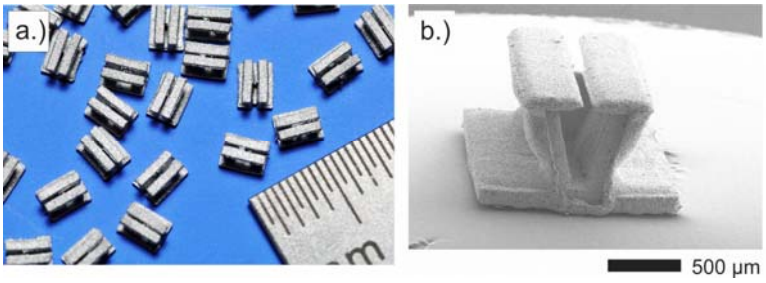
a.) Sintered + electropolished
b.) Cooling, mechanically opened
c.) Shape recovery after heating to body temperature
d.) Surpressed shape recovery

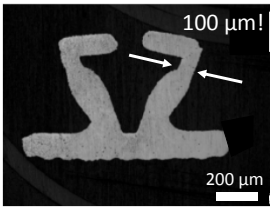
L. Krone, PhD thesis, Forschungszentrum Jülich.
L. Krone , M. Bram et al., Adv. Eng. Mat., 7 (2005) 613 – 619.

Arbeitsgruppe Martin Bram, Stand 26.03.2013

Prototype of Orthodontic Brackets (Steel 316L)

JÜLICH FORSCHUNGSZENTRUM





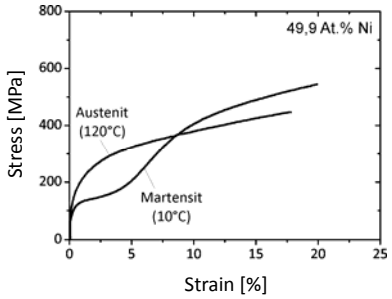
Cross section:
wall thickness < 200 µm !

Orthodontic Bracket:
Guiding of NiTi-wire
(Correction of dental malpositions)

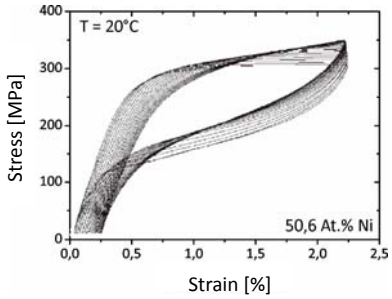
M. Bitzer, PhD thesis, Forschungszentrum Jülich, 2013.

Mechanical properties
NiTi-tensile sample (made by MIM)

Static tensile test (0.5 mm/min)



Cyclic test (0.1 mm/min):
> 50 Zyklen up to 2 % deformation

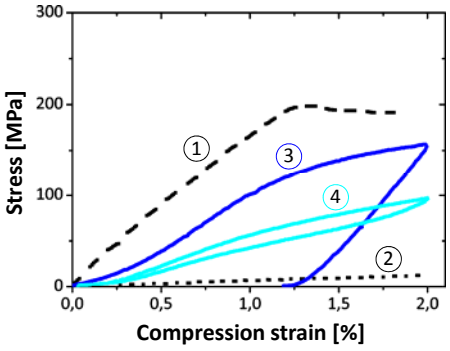


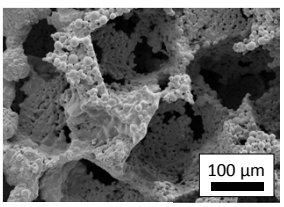
Even in the case of powder metallurgical production:
fully pronounced shape memory properties

Krone L. et al., Adv. Eng. Mat. **7** (2005) 613.
Mentz J. et al., Adv. Eng. Mat. **8** (2006) 247.

Arbeitsgruppe Martin Bram, Stand 26.03.2013

Highly porous NiTi for bone replacement





1) Cortical bone
2) Spongious bone
3) Titanium, porosity 50 %
4) NiTi, porosity 50 %
(Pseudoelasticity)

Bone as load-bearing damping system of human body.

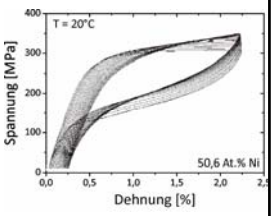
Porous NiTi adapts mechanical properties of bone better than any other metallic implant material.

Köhl M. et al., Adv. Eng. Mat. **11** (2009) 959.
Bram M. et al., J. Mat. Eng. and Perf. **20** (2011) 522.
Cysne Barbosa A.P., Powder Injection Moulding Int. 6 (2012) 59.

Summary

Development and optimization of processing technologies
- Cost-effective net-shape production
- Reproducibility
- Manufacturing of prototypes

Application-oriented characterization
- Mechanical properties (static, dynamic)
- Interaction on interfaces
- Basic characterisation in the laboratory
- Proof of function in real environments



Acknowledgements

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Martin Bitzer

Prof. Dr. Alexander Laptev
Dr. Nihan Tuncer

Dr. Thomas Imwinkelried
Dr. Thomas Ebel
Martin Wolff
Prof. Dr. Jurek Duszczyk
Dr. Evert J. van Langelaan
Prof. Dr. Michael de Wild