Micromoulding of Metals and Ceramics

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  Micro Powder Injection Moulding (MicroPIM)

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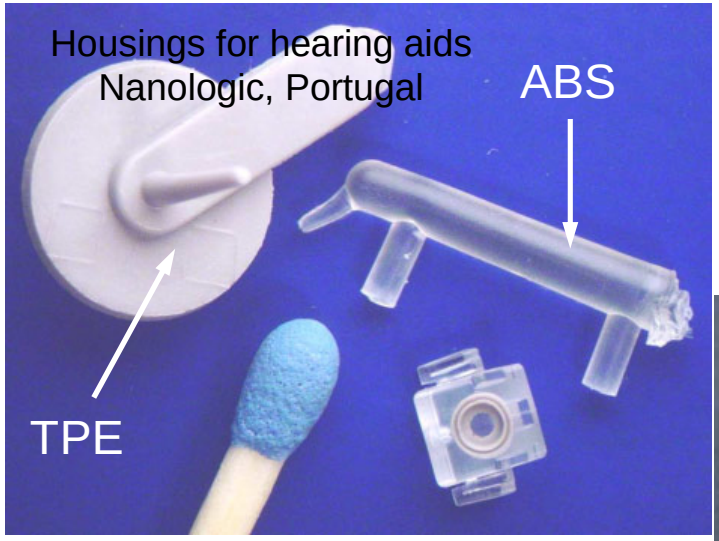
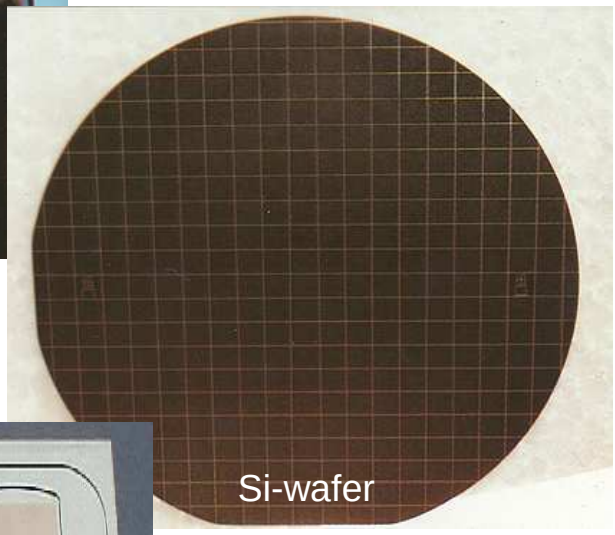
  - material/functional combinations
  - fixed connections
  - movable connections

- Micro Inmould-labelling using PIM-Feedstocks

- Outlook

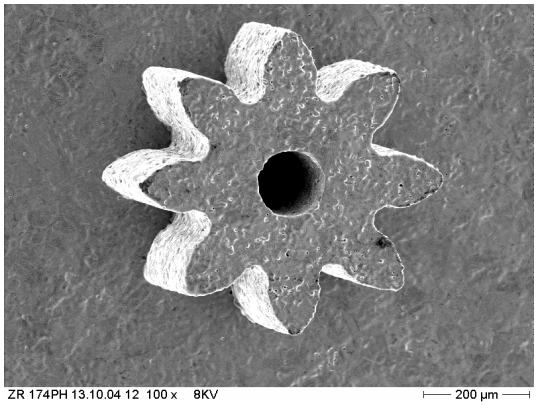
Common materials in MST

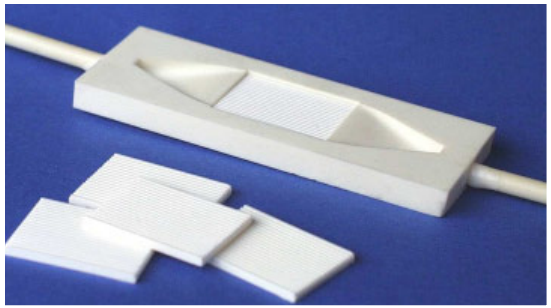




... and what about steels and ceramics ?

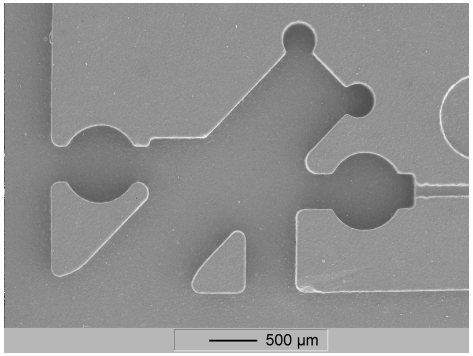
mechanics: **forces, momentums, abrasion**

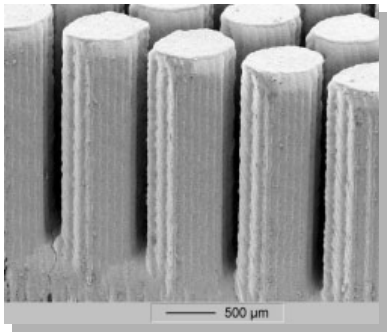




chemistry/analytics: **corrosion, temperature**

telecommunication: **thermal expansion**





functional materials: **conductivity, PZT etc.**

Options for manufacturing metal and ceramic micro parts

replicative

additive

e. g.
laser-sintering

subtractive

e.g.
micromechanical processes
(milling, drilling, EDM etc)

galvanoforming

electrophoresis

metal casting

powder technology

powder injection moulding (MicroPIM)

metal ***(MicroMIM)***

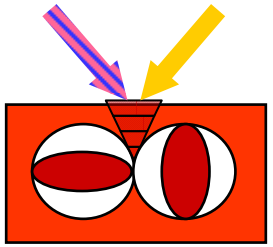
ceramic ***(MicroCIM)***

powder pressing

} ***broad range of materials***
high economic efficiency
various design options

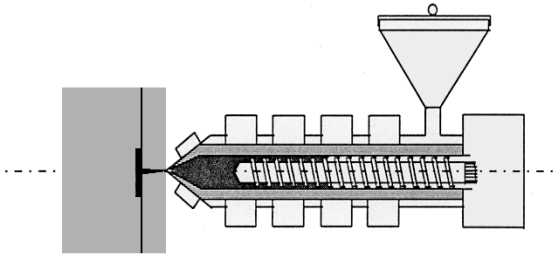
Powder Injection Moulding (PIM)

Powder Binder

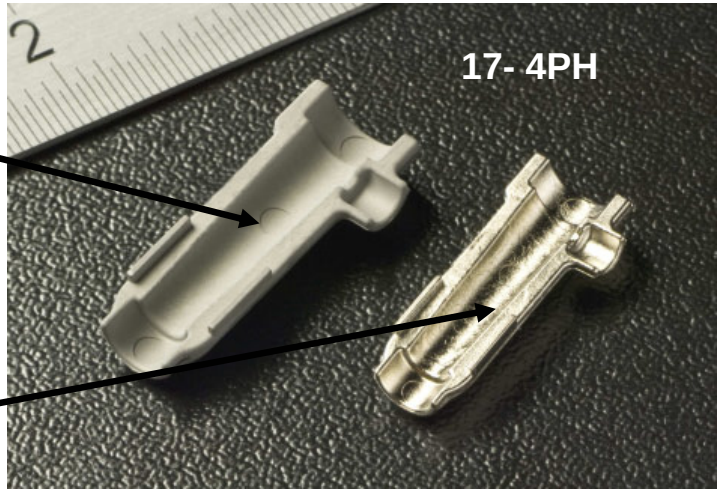


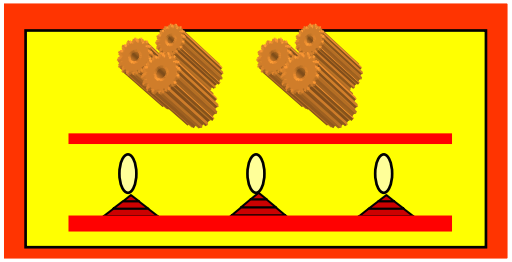
Feedstock preparation

Sinter shrinkage
(15 – 23 % linear) depending on powder/binder mixing ratio



Shaping by (micro) injection molding





Debinding and sintering

PIM-Materials (selection)

Metal	tempering steel	42 CrMo 4, 40 NiCrMo 6
	case-hardened steel	21 NiCr Mo 2, 16 MnCr 5
	tool steel	100 6W 5Mo 4 Cr 2V
	stainless steel	X20 Cr 13, X6 Cr 17
	austenitic stainless steel	X2 CrNiMo 17 13 2 (316L, 1.4404)
	precipitation hardening steel	X5 CrNiCuNb 17 4 (17-4PH, 1.4542)
	low-alloyed iron	Fe2Ni, FeNi7
	softmagnetic materials	carbonyl-Fe, Fe50Ni, FeSi3
	covar	Fe 29Ni 17Co
	copper	Cu, CuNi50, CuFe
	titanium	Ti6Al4V, TiAl7Nb
	nickel-base alloys	NiCr 22 Fe 18 Mo, NiCr 20 Co 18 Ti
	refractory metals	W, W-La_2O_3, WNiFe, WCu10, MoNb13, Mo20Cu
Hard metals, Cermets	carbides, nitrides	WCxCo, TiN
	cermets	Mo-Al_2O_3, Fe-TiC
Ceramic	oxide-ceramics	Al_2O_3, ZrO_2, ZTA, ATZ
	nonoxide-ceramics	Si_3N_4, SiC, AlN
	functional ceramics	PZT, TiN

PIM – industrial applications

worldwide market **MIM:** **~ 1.000 Mio. US-$**

CIM: **~ 400 Mio. US-$**

Maxxon Motor GmbH

Krone GmbH

Bernhard Förster GmbH

Contrary demands on MicroPIM powders

contour details and surface quality: **powder size as fine as possible**	⟷	**good flowability and low sintering shrinkage:** **powder size as large as possible**

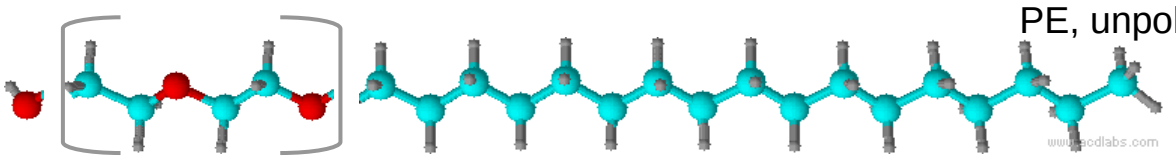
current compromise: particle sizes between 0.2 µm (ceramic) – 4 µm (steel)

Solutions:

- **optimized additions of dispersants**
- **multimodal mixtures of nano- and micropowders**

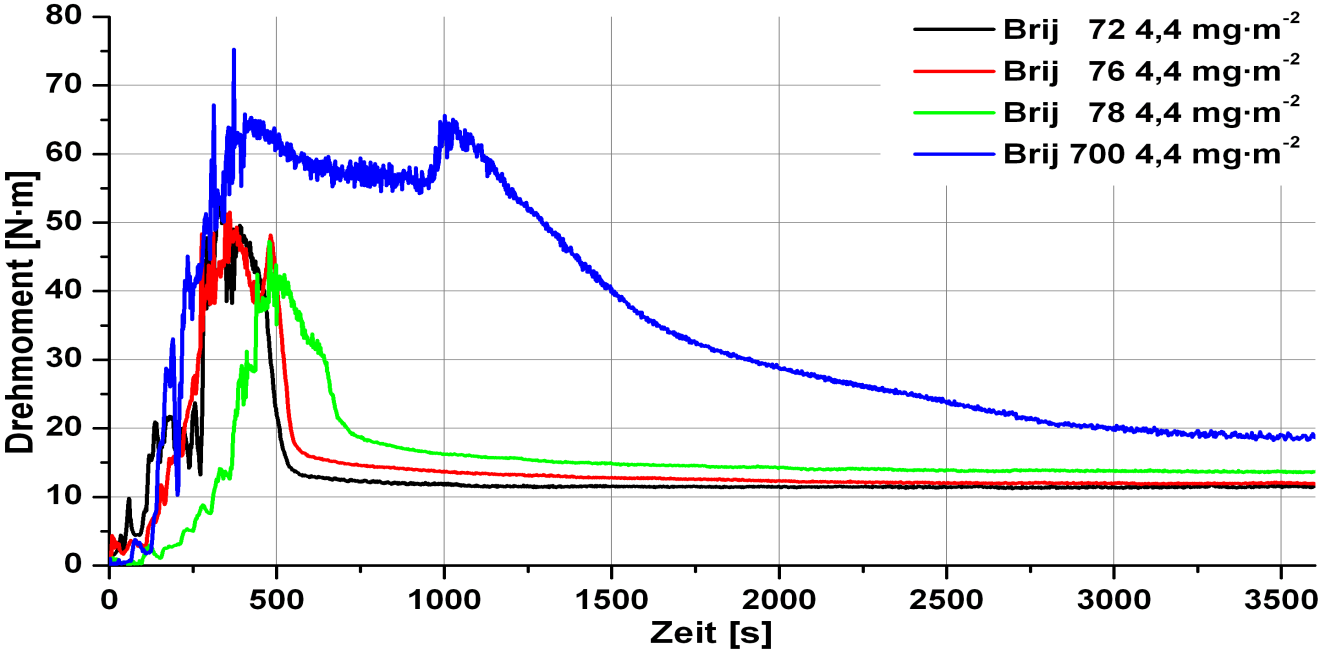
Binder optimization using tailored dispersants

Brij 72,76,78,700
Sigma Aldrich



PE, unpolar

Glycol, polar (2, 10, 20, 100)



optimized dispersant content

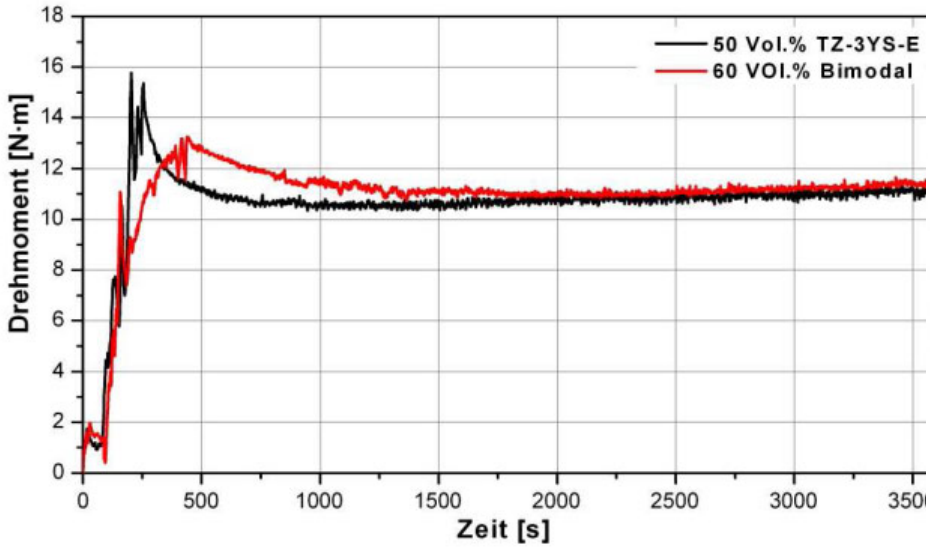
reduced glycole chain length leads to lower energy input and viscosity

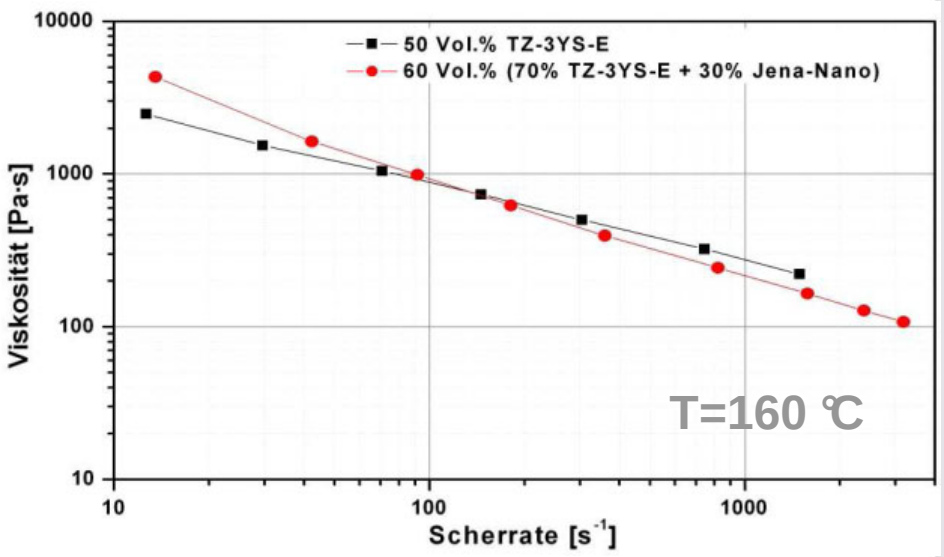
=> increased powder content (≥ 50 Vol.%)

Increasing powder content by using bimodal powders

bimodal: **60 vol.%** powder content (70 % rough + 30 % fine)

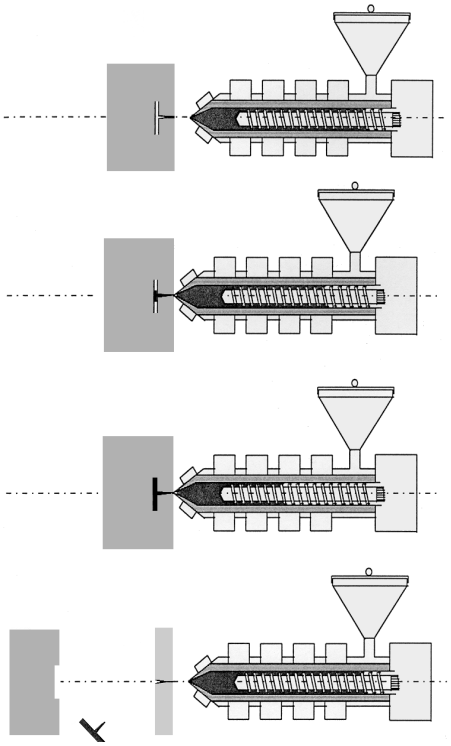
monomodal: 50 vol.% powder content (100 % rough)





Increasing the powder content from 50 → 60 vol.% while processibility and viscosity remain equal

Specialities

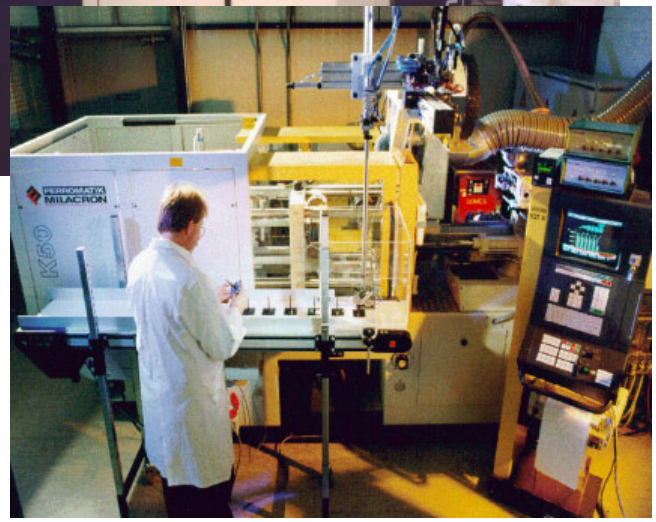


Closing + Heating of mold core
Plastification of feedstock

Evacuation of moulding tool
Injection of feedstock

Dwell pressure phase
Cooling of moulding tool

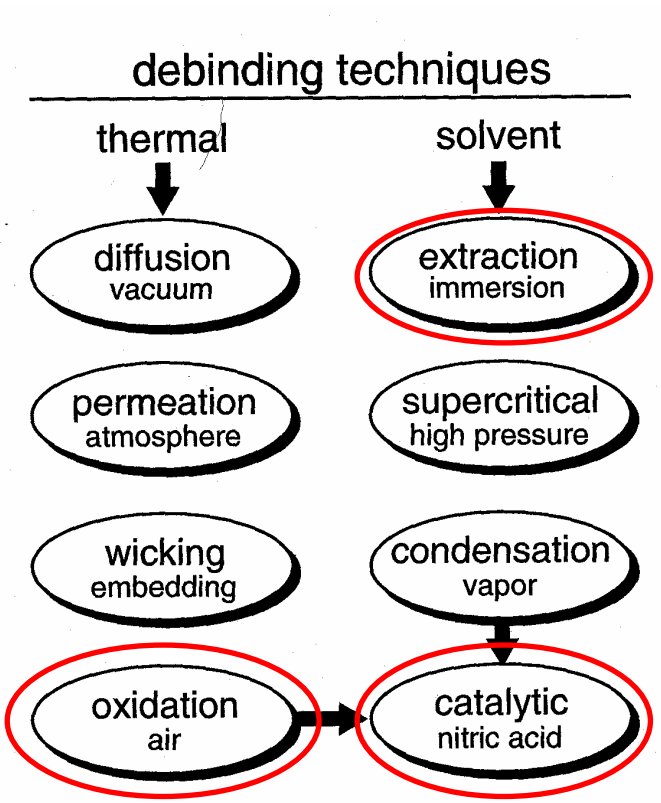
Precise tool movements
Ejection and handling



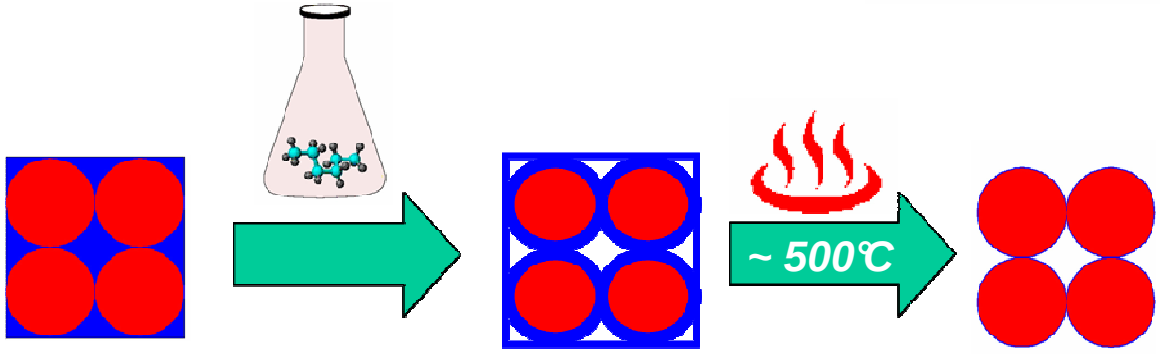
Heating / Cooling = Variotherm-process necessary for replication of high aspect ratios

MicroPIM - Debinding

Extraction of the organic binder



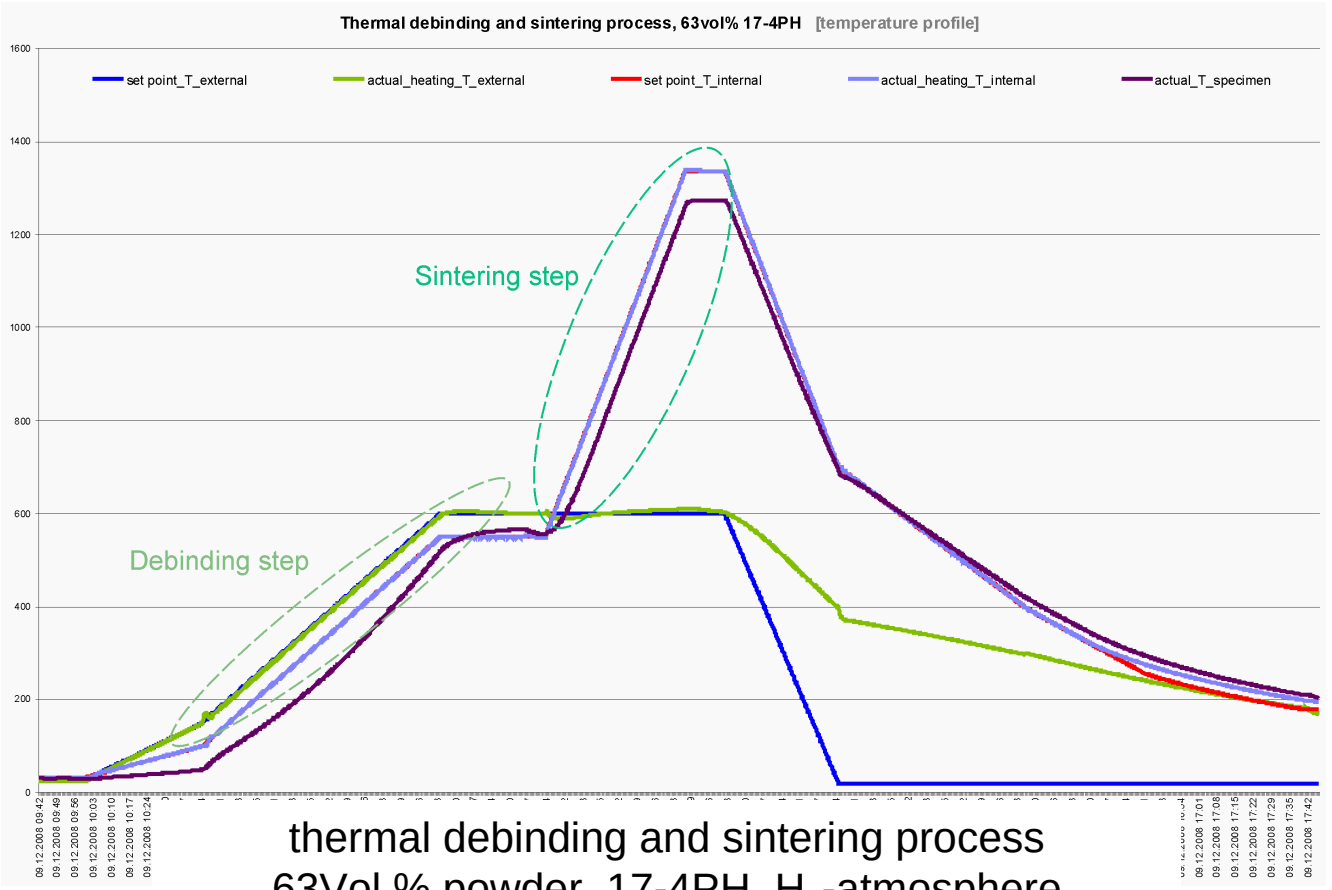
R. German
San Diego SU



at KIT approved for MicroPIM:

solvent pre-debinding
thermal main debinding

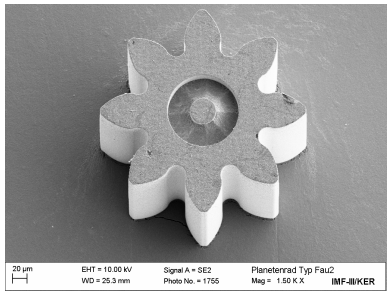
MicroPIM - Sintering



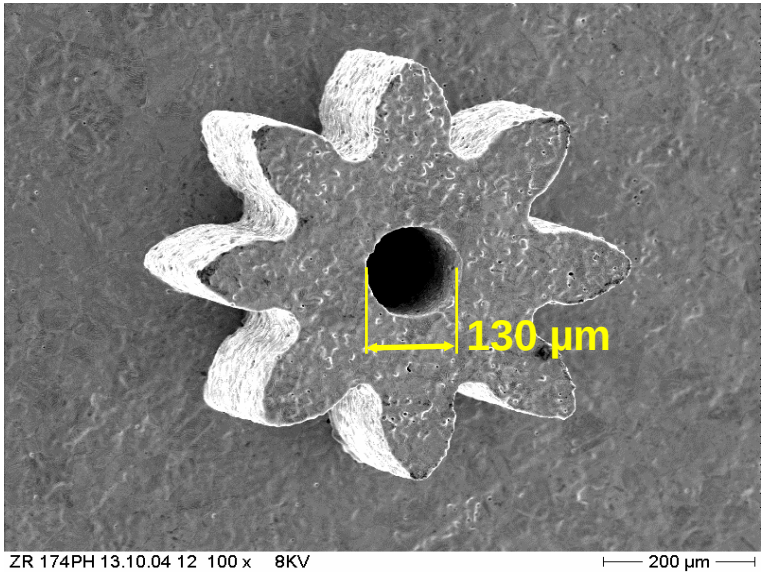
thermal debinding and sintering process
63Vol.% powder, 17-4PH, H_2-atmosphere

- densities of up to **96 – 99%** of theo. density achieved
- generation of **fine grain sizes** by optimized heating- and cooling rates

MicroPIM

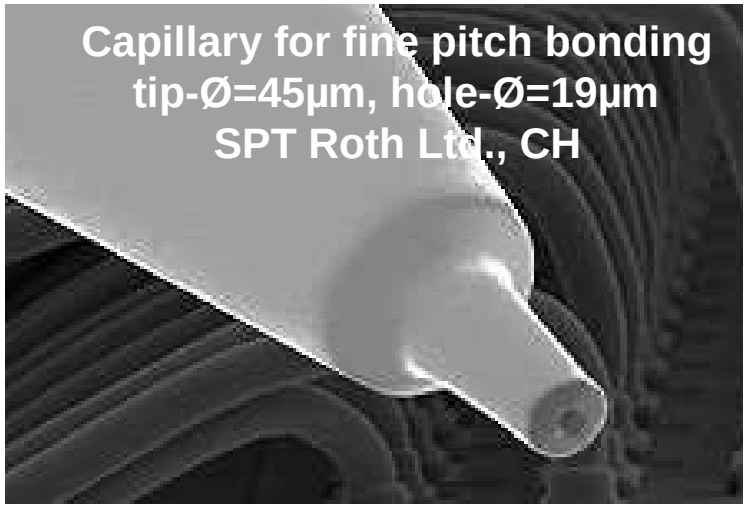


Ceramic gear wheel
outer-∅ approx. 275 µm



Micro gear wheel made of steel
17-4PH, outer-Ø = 610µm

EPMA Award 2008 to Parmaco
Metal Injection Molding AG, CH



Micro Injection Moulding – General Data

Materials	min. lat. Dimension [µm]	min. Detail [µm]	max. Height [µm]	Aspect ratio [isolated walls]	Aspect ratio [grooves]	Tolerance [%]	Roughness ** R_{max} / R_a [µm]
Plastics	10	<0.1	2500	>20 (200*)	25	± 0.05	0.05 / <0.05
Metals	50	10	1300	>10	>10	< ± 0.5	7 / 0.8
Ceramics	<10	<3	1300	<15	15	± 0.3***	2 / <0.3

* flow length to wall thickness ratio ** depending on mould insert
*** down to ± 0.1% under certain conditions

Multi-Component Micro Powder Injection Moulding

Objectives

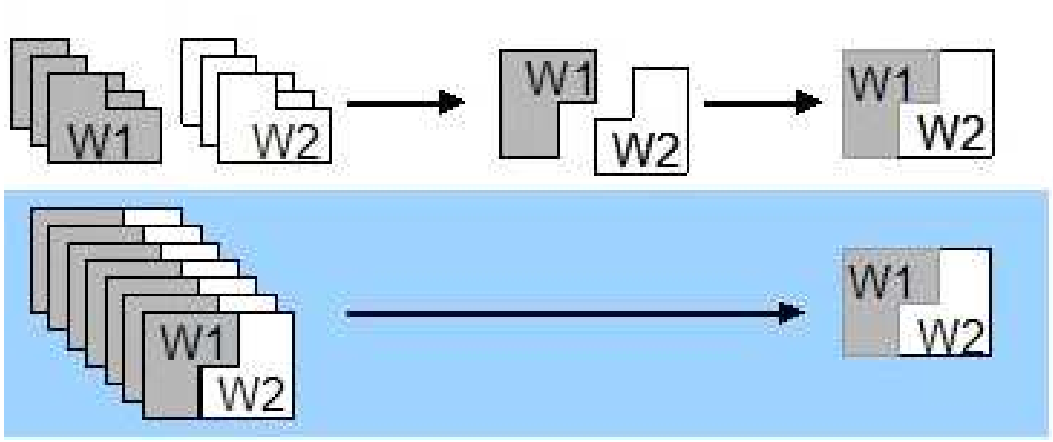
Functions integration by combining different materials

Realization of (im-)mobile connections

Reduction of handling and assembly expenditure

single-piece fabrication
+ assembly

2C-MicroPIM
– assembly



2C-MicroPIM – Mobile + Immobile Connections

Basic Rules

	Mobile	Immobile
Binder system	n. r.	compatible
Powder loading	inner section < outer section	nearly equal
Sinter temperature	inner section < outer section	nearly equal
Thermal expansion	almost equal	nearly equal

2-component PIM

Combination of a magnetic steel (17-4PH, 1.4542) with a non-magnetic steel (316L, 1.4404)

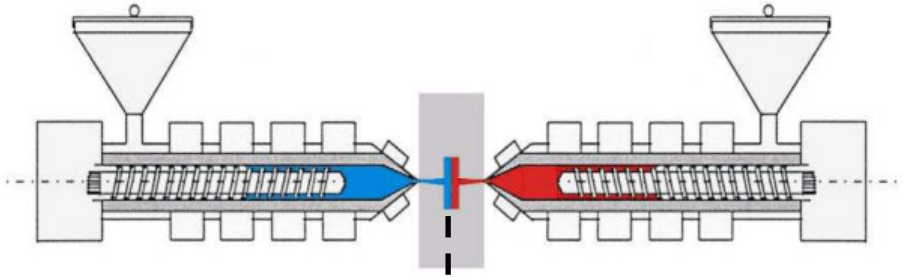
Hard metal WCxCo with different Co-contents (16% and 6%), ARBURG

2-componenten MIM, AMT, Singapore

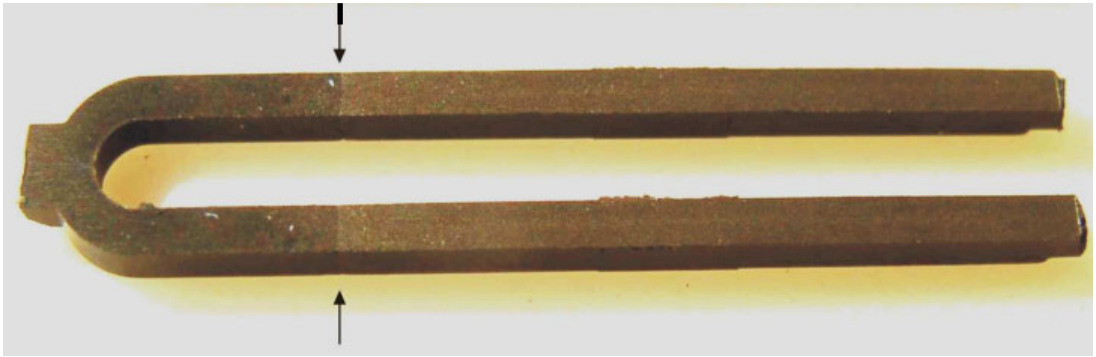
2C-MicroCIM

Material: Al_2O_3/TiN-mixture, **electrical conductivity** according to TiN-content

Demonstrator: ceramic heating needle



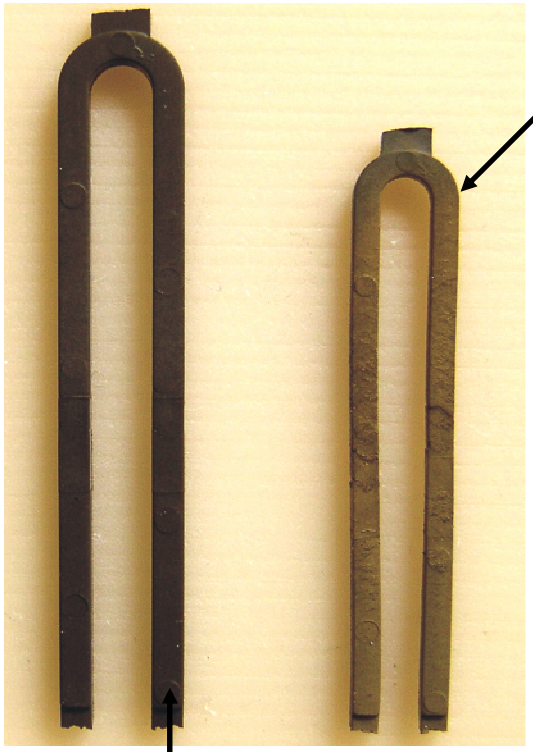
Feedstock 1 Feedstock 2



TiN-content ↓
R_{spez} ↑

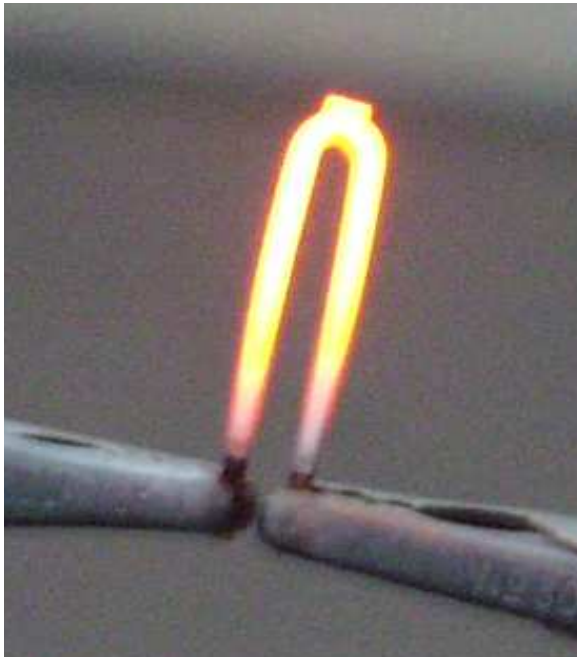
TiN-content ↑
R_{spez} ↓

2C-MicroCIM



Adjustment of sintering shrinkage by variation of powder content

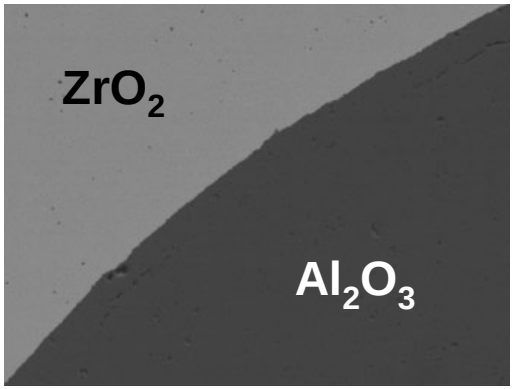
Green body
length = 22 mm
cross section = 1 mm²



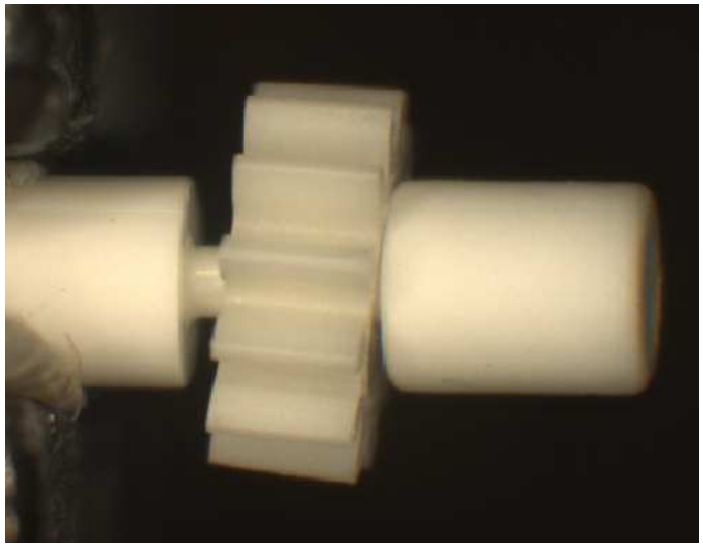
Function test run of ceramic heating element

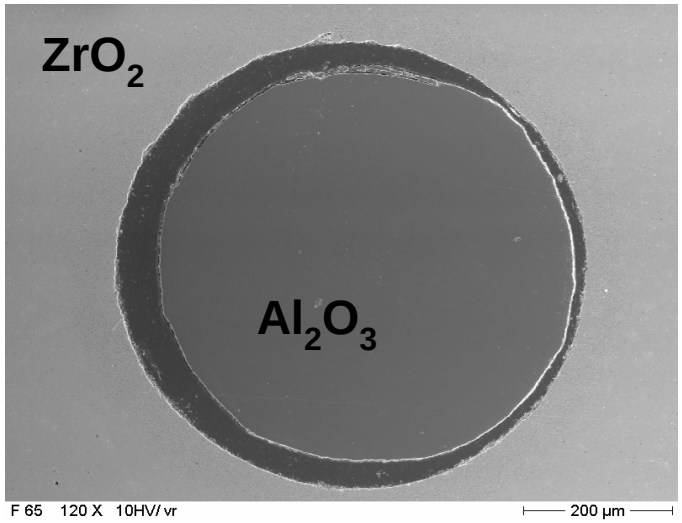
2C-MicroPIM

Immovable connection of thermodynamically unmixable ceramics



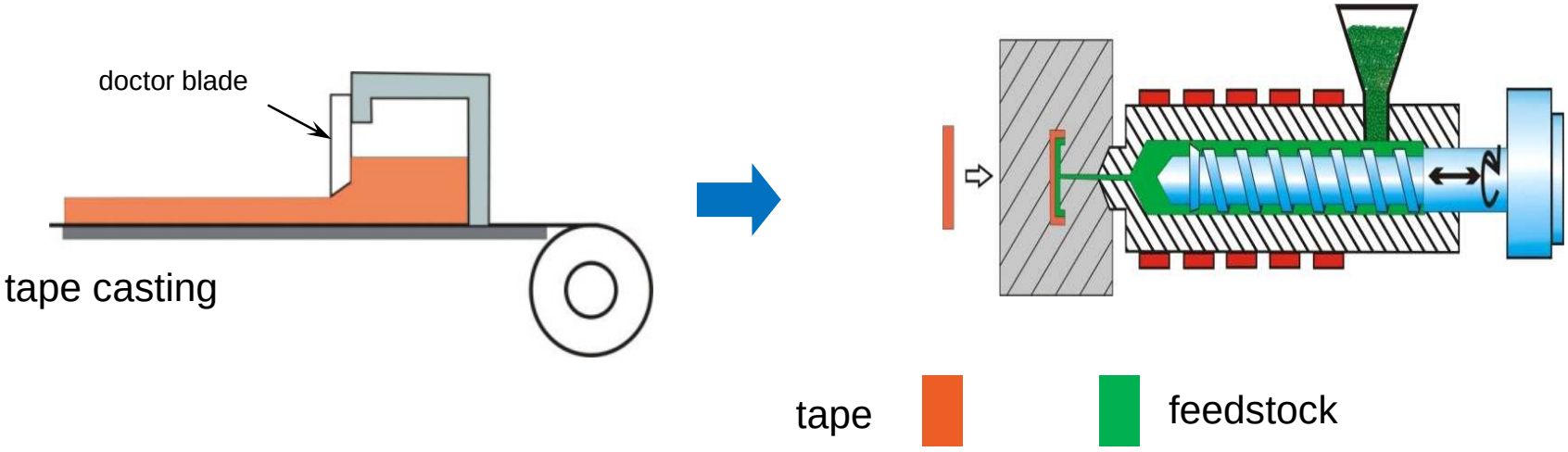
Realization of movable connections





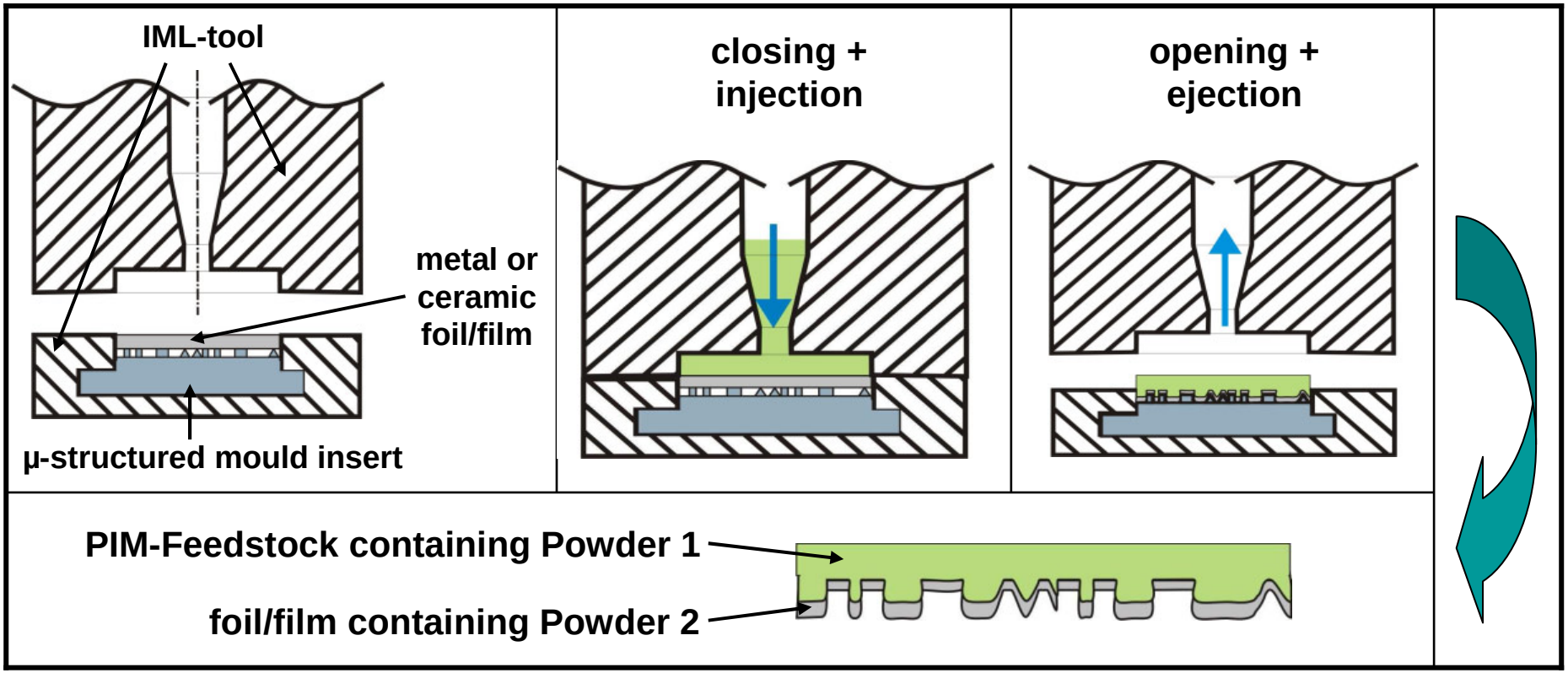
Micro Powder Inmould-labelling (IML-MicroPIM)

- combining the advantages of two shaping methods …



EU Project No. FP7-NMP4-2007-214122

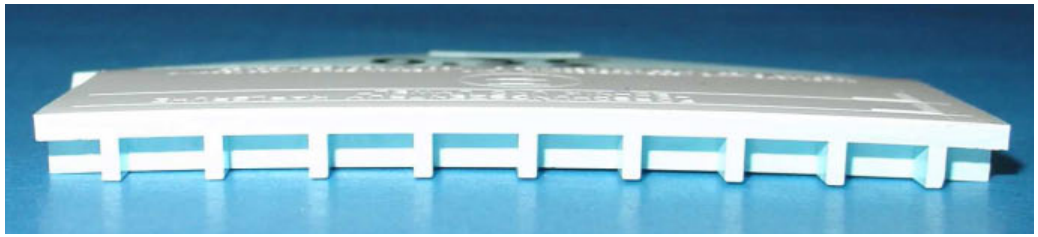
Micro Powder Inmould-labelling



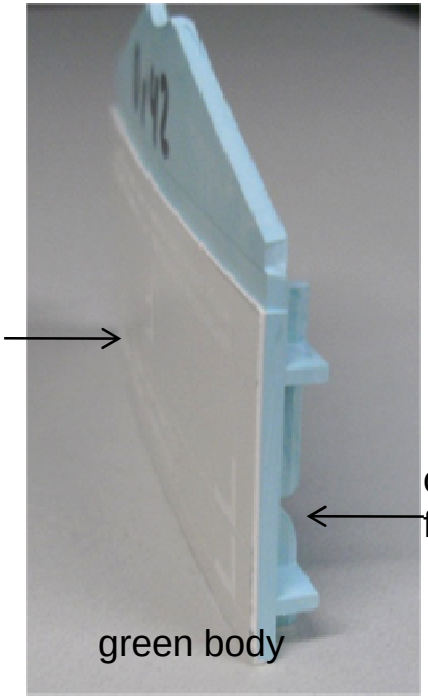
Powder 2: functional or nano-particles applied on the structured surface

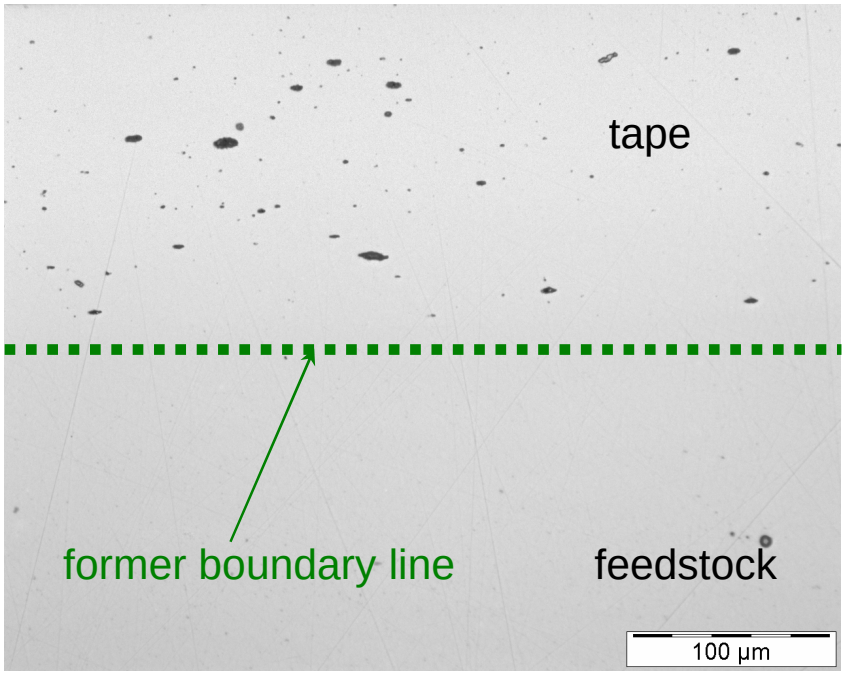
→ **better contour accuracy, higher surface quality, functional properties etc.**

Current Results (ZrO_2)



green body





sintered part

Outlook

- Expanding the range of **materials**

  functional materials

  fine and nano powders etc.

- Improvement of **dimensional accuracy** and **surface quality**

- Enhanced **multi-component** process variants

  e.g. EU-Project „Multilayer“

- **Special Software** for Simulation of MicroPIM

Acknowledgment

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Thank you !