Micro Injection Moulding
and
Multi Component Micro Injection Moulding

V. Piotter, E. Honza, A. Klein, T. Mueller, K. Plewa

Karlsruhe Institute of Technology (KIT)

Institute for Applied Materials (IAM – WPT)

KIT – die Kooperation von Forschungszentrum Karlsruhe GmbH und Universität Karlsruhe (TH)
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Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft

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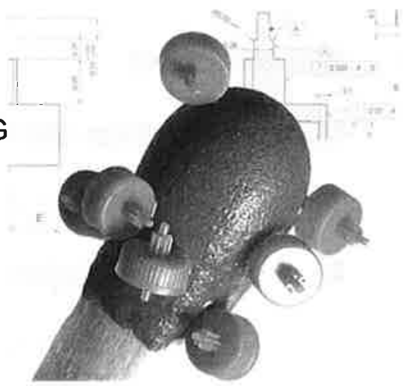
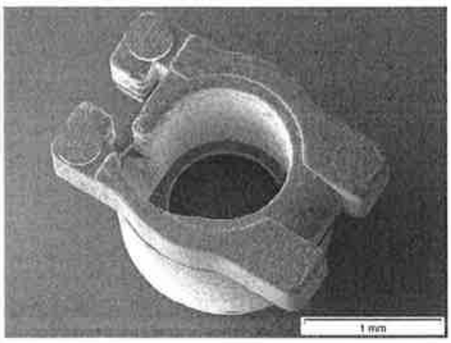
Micro Fabrication Processes

Process / Material	µ-Replication (primary shaping)	µ-Forming (re-shaping)	Subtractive µ-processes	Additive µ-processes (+ joining)
Polymer	**Injection Moulding** reaction moulding PVD, CVD rolling/calendaring extrusion, melt spinning	embossing NanoImprint bending, drawing rolling	lithography: (UV, e-, DXL, laser) etching, plasma etching, RIE, micromachining	laser joining ultrasonic welding stereo lithography
Metal	electroplating **MIM** casting powder pressing	embossing bending drawing	micromachining, grinding, EDM, ECM, laser, water jet, punching/stamping (plasma) etching, RIE	laser joining laser sintering soldering welding (e-, diffusion) stereo lithography
Ceramic	**CIM**, casting sol-gel-processes electrophoresis extrusion	embossing of green bodies	laser, micromaching of green bodies lithography: (UV, DXL, laser)	soldering (glass, brazing sold.) laser sintering stereo lithography
Silicon	epitaxial growth [CVD]		wet etching plasma etching, RIE	anodic bonding diffusion bonding

Micro Injection Moulding of Polymers

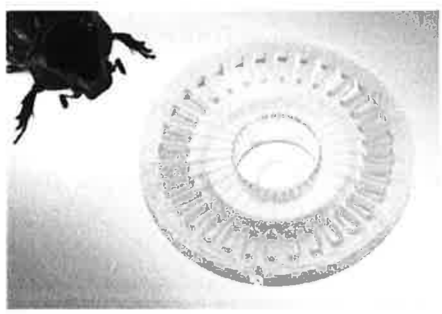
Micro gear wheels, POM
Rolla Micro-Synthetics AG





Switch housing, LCP
mass: 0,0022 g
H. Scholz GmbH

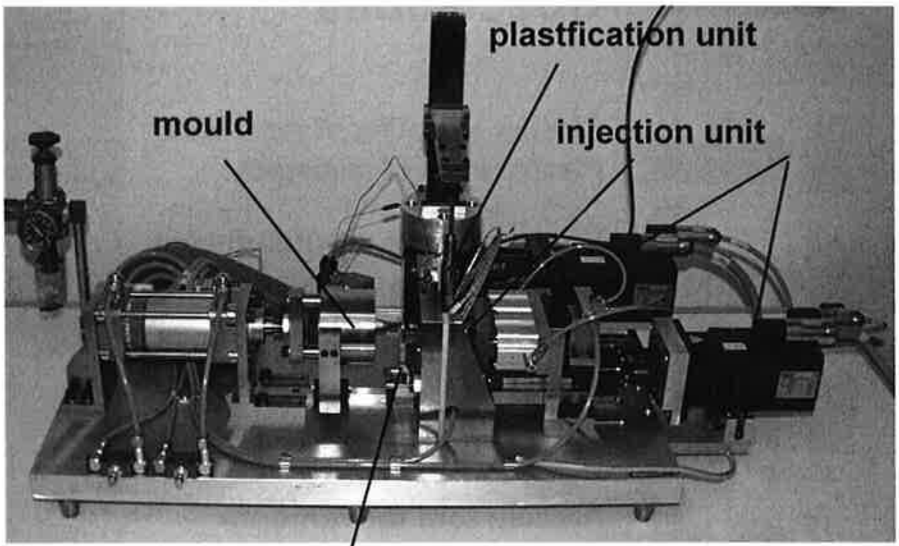
Bio-Disc, PC, PMMA
Reiner GmbH



1-Component µIM - Machinery

IKV, RWTH Aachen

Forschergruppe 702



Laboratory IM-machine with ultrasonic plastification for lowest shot weights

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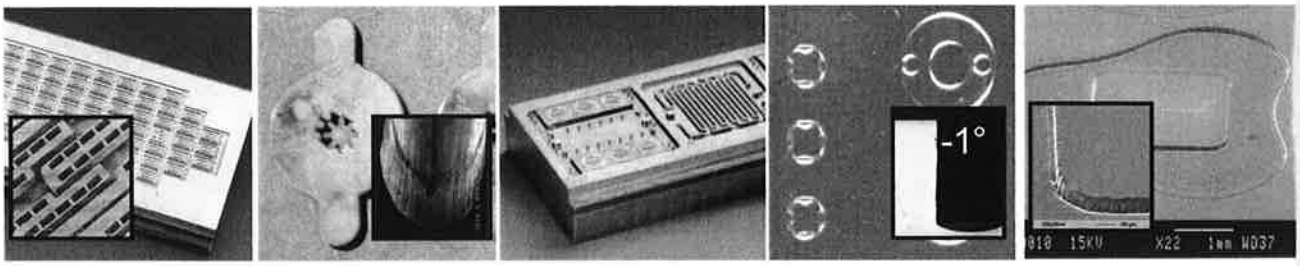
1-Component µIM - Tooling

methods to produce microstructured inserts



LIGA	SU8	Micro-Cutting	Silicon	Laser
X-ray lithography + galvanoforming	UV-light + galvanoforming	Micro-cutting, -milling, -drilling	Si-etching	Laser-Ablation
Nickel, (Ni-all.)	Nickel, (Ni-all.)	Brass, Steel	Silicon	Steel, HM, Ceramic
+ AR = 20-30	+ ejection slopes	+ ejection slopes	AR = 5	wear resistant
+ R_{max} = 0.04µm	AR = mind. 5	AR = 5-10	- cut-backs	AR = 5 (10)
- time for delivery	- roughness	R_{max} = 0.2 – 0.5µm	- critical	- R_{max} = 2µm

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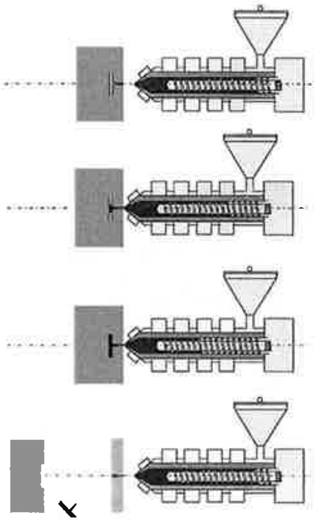
Micro Injection Moulding

Specialities



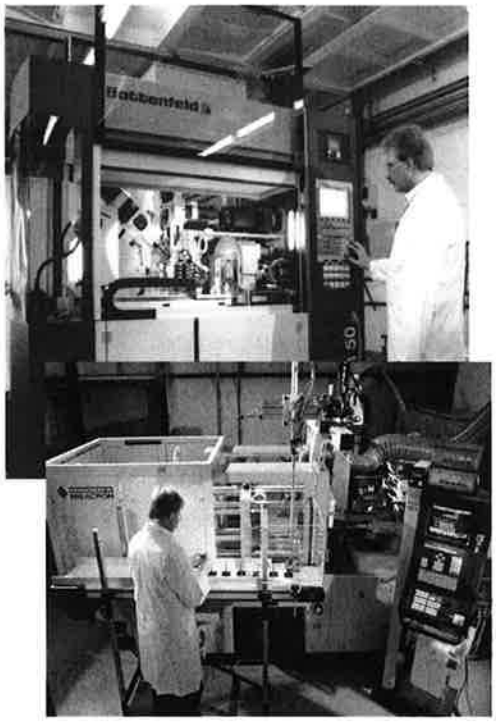
Closing + Heating of mold core
Plastification of feedstock

Evacuation of moulding tool
Injection of feedstock

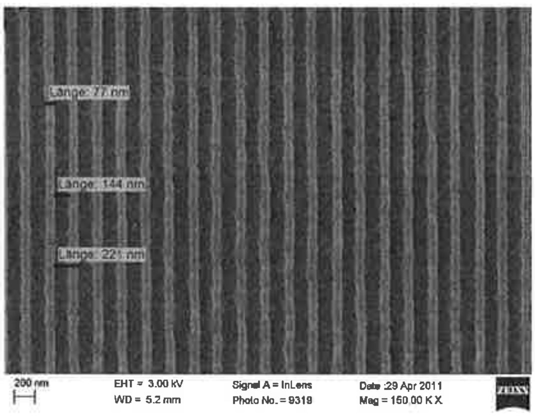
Dwell pressure phase
Cooling of moulding tool

Precise tool movements
Ejection and handling

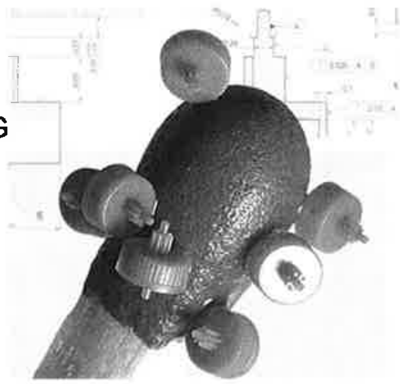
Heating / Cooling = Variotherm-process necessary for replication of high aspect ratios



Micro Injection Moulding of Polymers



Micro gear wheels, POM
Rolla Micro-Synthetics AG



Micro grating structure
pitch ≤ 80nm, PMMA
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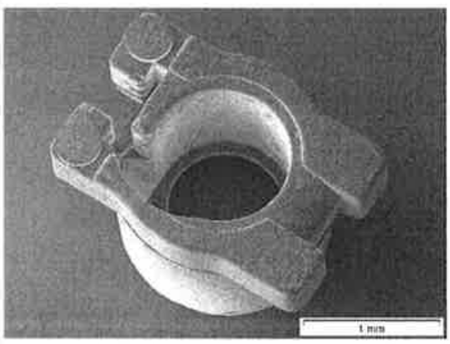

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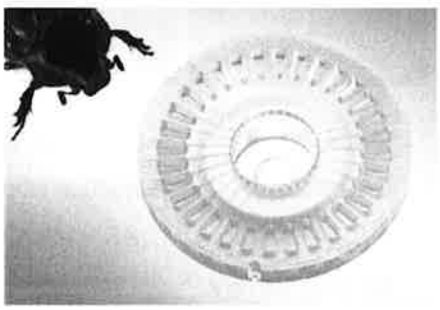
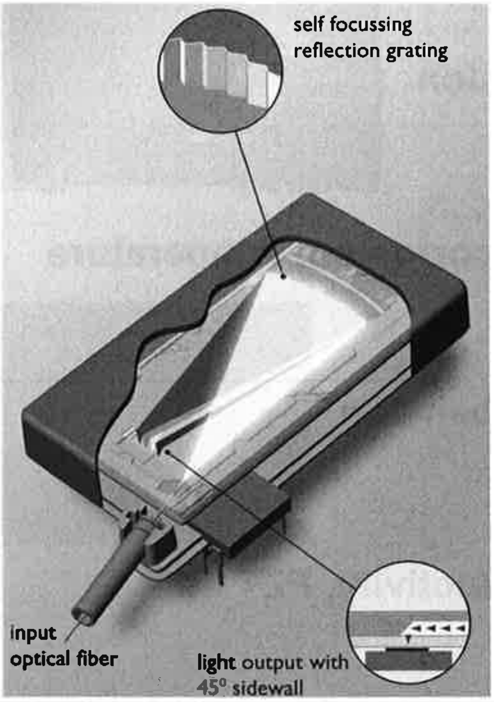
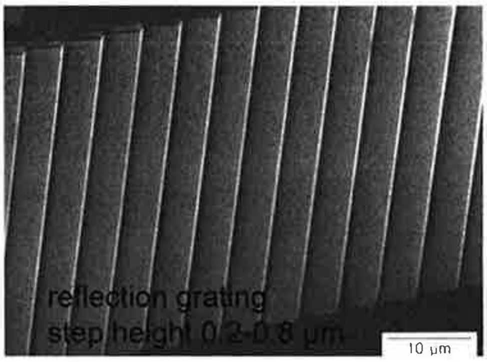
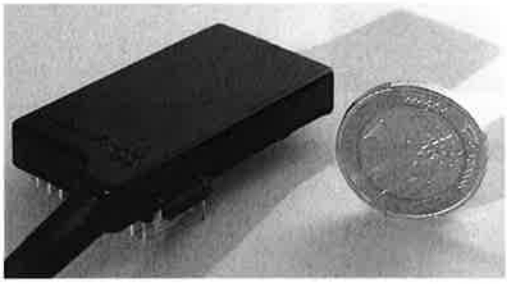


Micro Injection Moulding of Polymers

Micro Spectrometer



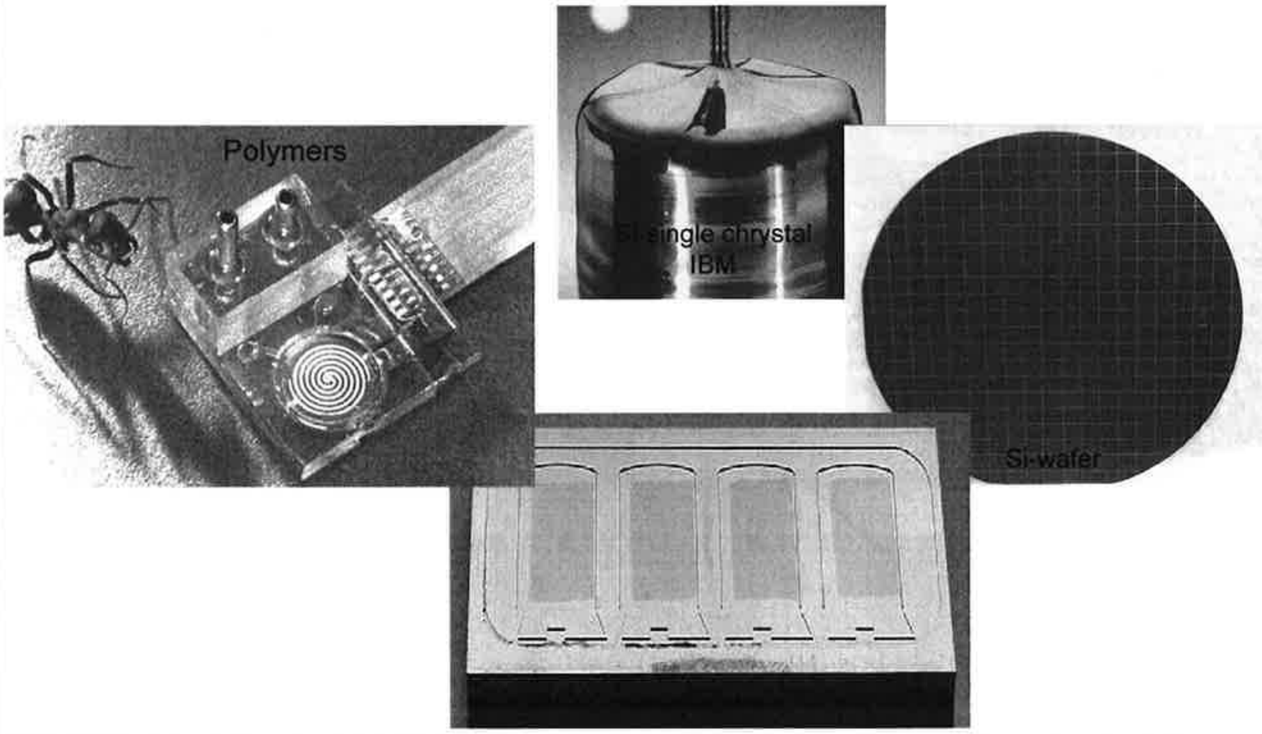




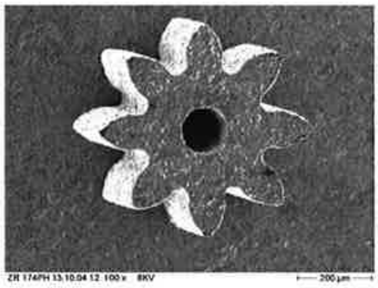
finally assembled micro spectrometer

Source: Boehringer Ingelheim MicroParts

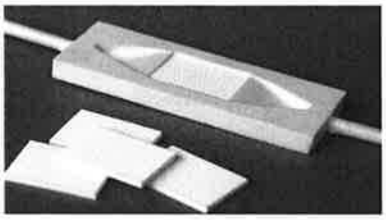
Common materials in Micro System Technology



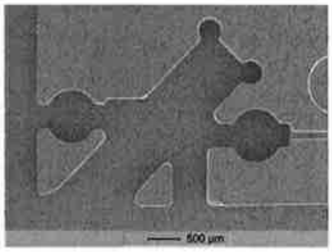
... and what about steels and ceramics ?



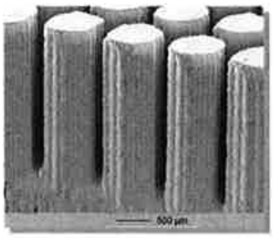
mechanics: forces, momentums, abrasion



chemistry/analytics: corrosion, temperature



telecommunication: thermal expansion



functional materials: conductivity, PZT etc.

Micro Powder Injection Moulding

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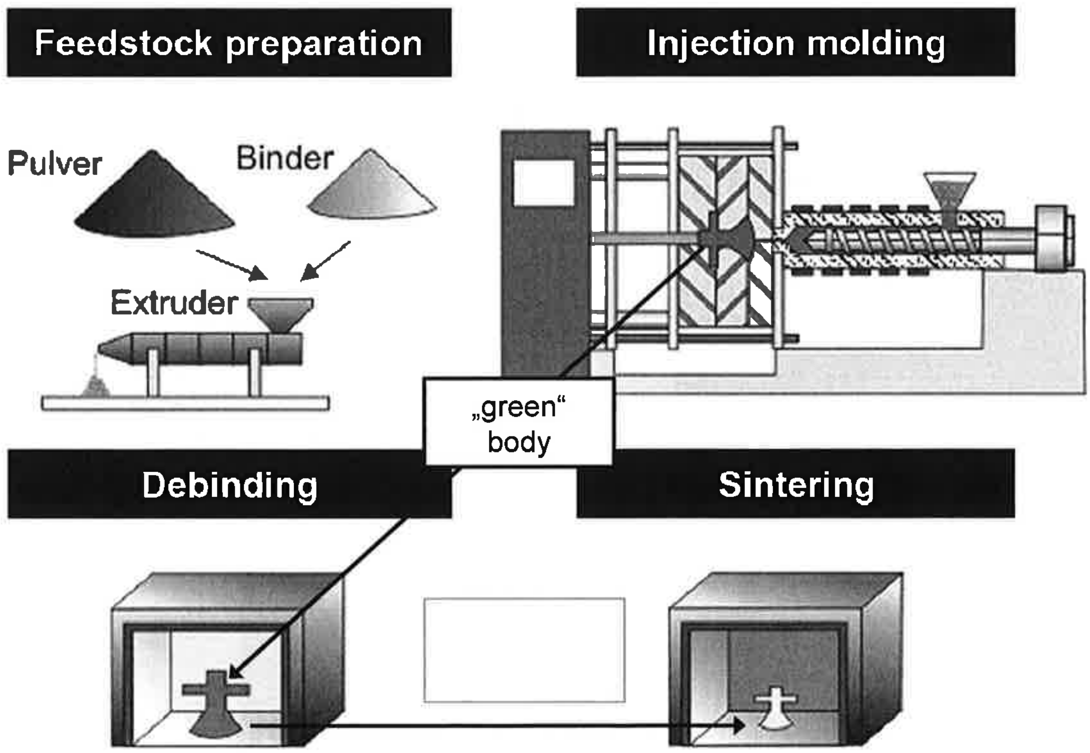


Micro Powder Injection Moulding

Driving Forces for MicroPIM

Economical Motives	Technological Motives
	expanding the range of materials

PIM-Materials (macroscopic, selection)

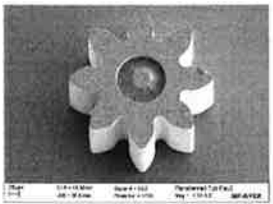
Metal	tempering steel	42 CrMo 4, 40 NiCrMo 6
	case-hardened steel	21 NiCr Mo 2, 16 MnCr 5
	tool steel	100 6W 5Mo 4 Cr 2V
	stainless steel	X20 Cr 13, X6 Cr 17
	austenitic stainless steel	X2 CrNiMo 17 13 2 (316L, 1.4404)
	precipitation hardening steel	X5 CrNiCuNb 17 4 (17-4PH, 1.4542)
	low-alloyed iron	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

Micro Powder Injection Moulding

Driving Forces for MicroPIM

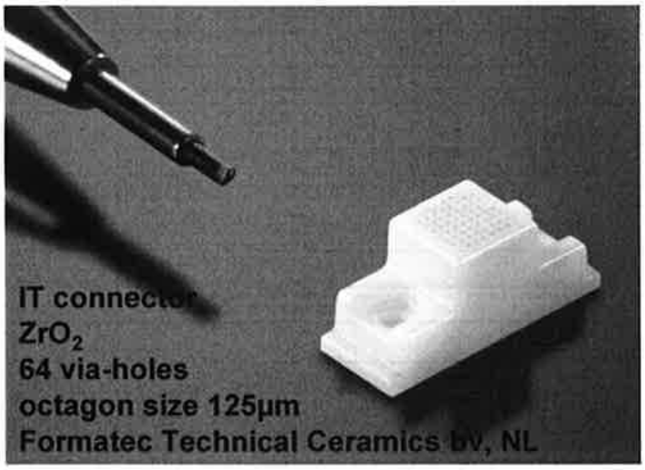
Economical Motives	Technological Motives
low costs in medium and large series production	expanding the range of materials
reduction of shaping steps	manufacturing of complex geometries
equipment based on standard machinery and tooling	several sub-variants of basic process
attractive for SME`s	certain material properties increase in micro dimensions

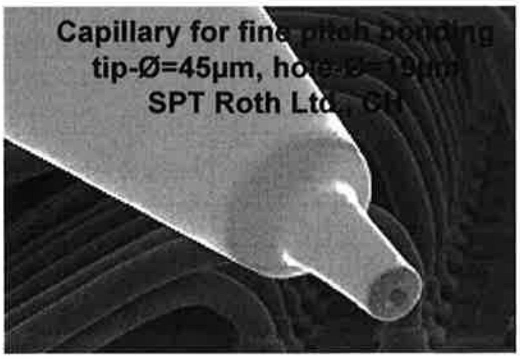
MicroPIM - Current Status



Ceramic gear wheel
outer-∅ approx. 275 µm

EPMA Award 2008 to
Parmaco MIM AG, CH





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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

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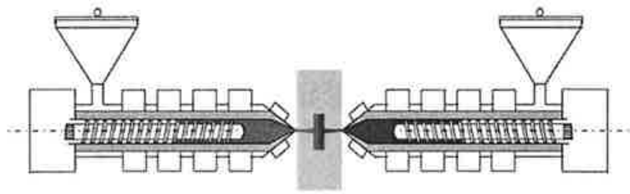
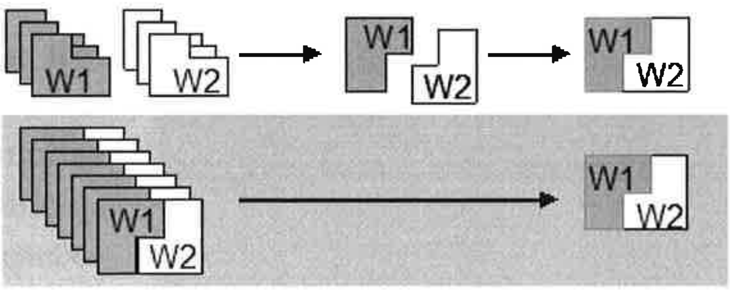
Multi-Component Micro Injection Moulding

Merging of two or more resins/feedstocks in one tool



single-piece fabrication + assembly

2C-µIM – assembly



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Multi-Component Micro Injection Moulding

Driving Forces for 2C-µIM

Economical Motives	Technological Motives
low costs in medium and large series production	production of multi-material devices
reduction of assembly costs	generation of fixed or movable connections
reduced energy, water, plant area etc. consumption	

2C-µIM - Machinery

FormicaPlast® with piston injection unit
(Ø = 2 × 3mm)
DESMA

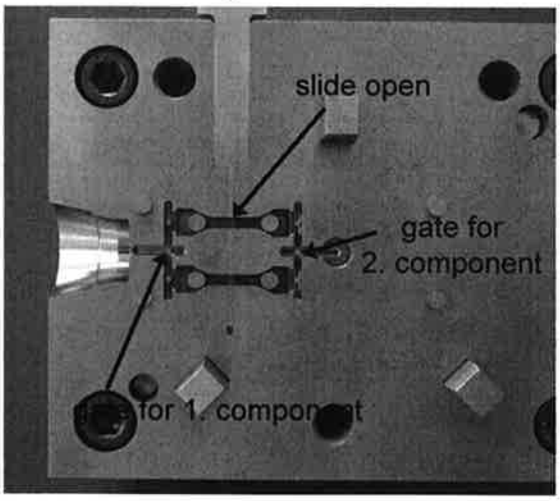
at KIT equipped with:
- tool evacuation
- variothermal temperization
- simultaneous or sequential injection
- additional compression steps (µICM)

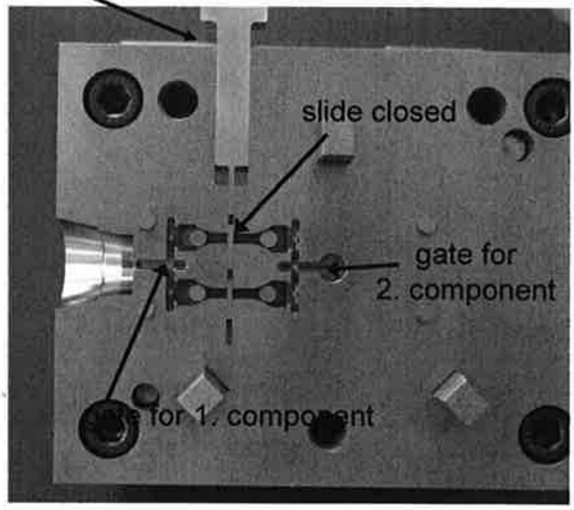
Multi-Component Micro Injection Moulding

Tool equipped with movable slide =>

simultaneous or sequential injection

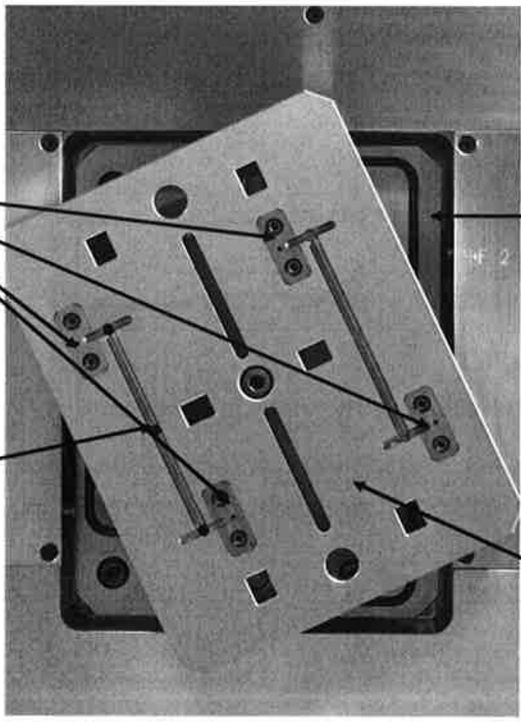
COTECH





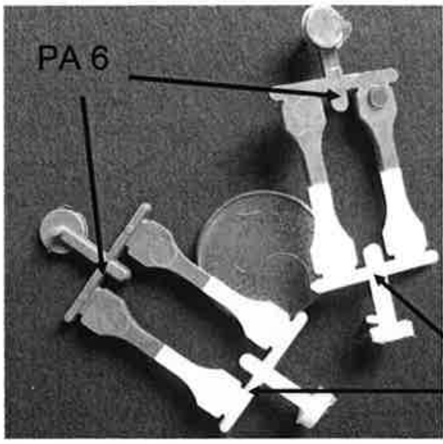
Multi-Component Micro Injection Moulding

Three-plate tool equipped with index plate

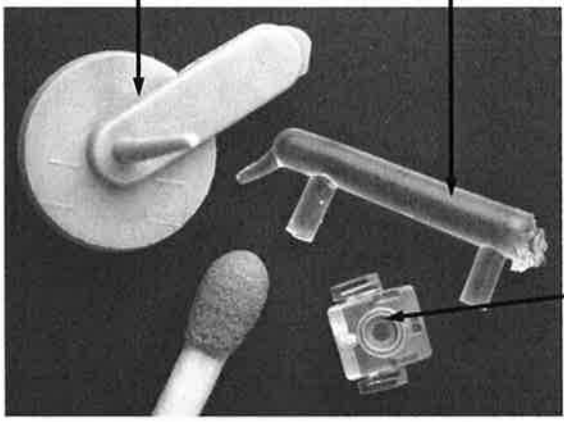


Multi-Component Micro Injection Moulding

Tensile test specimen to investigate interface strength, COTECH



TPE ABS

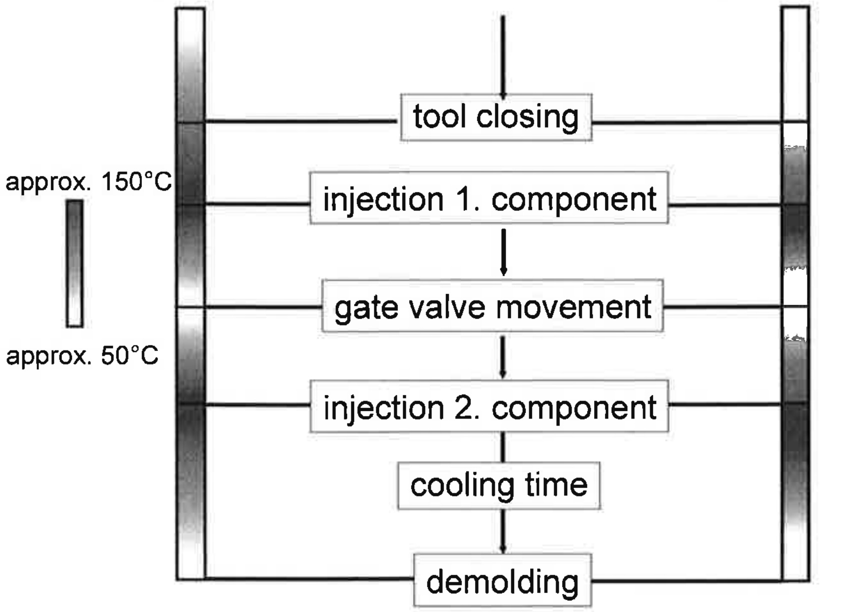


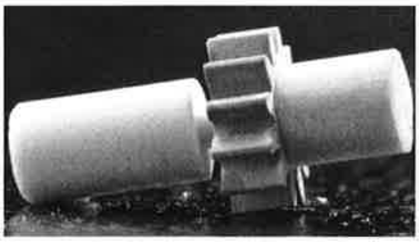
Source: Nanologic Ltd., Portugal

Housings for hearing aids
1. Injection housing ABS
2. Injection sealing TPE

2C-µIM - Process Conduct

in case of high aspect ratios





injection pressure

environmental pressure

vacuum

2C-MicroPIM - Basic Rules

2C-Micro Powder Injection Moulding

=> debinding and sintering steps have to be considered

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

2C-MicroPIM – Opportunities

Multifunctional Products

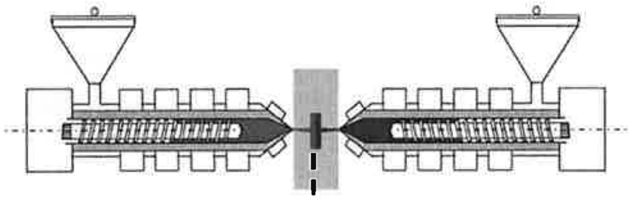
with complimentary or even contradictionary properties

conductive	↔	**insulating**
hard	↔	**tough**
magnetic	↔	**non-magnetic**
bio-compatible	↔	**mechanically strong**
tight	↔	**porous**

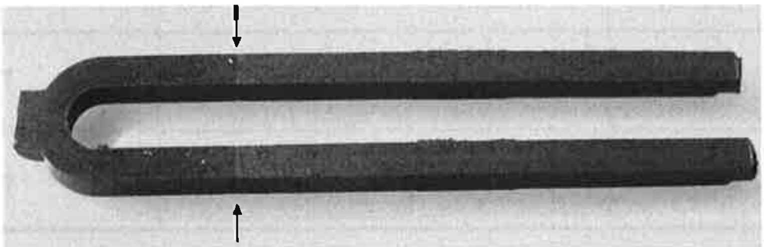
and others more ...

2C-MicroPIM – Immobile Connections

Material: Al_2O_3/TiN-mixture, **electrical conductivity** according to TiN-content
Demonstrator: ceramic heating needle



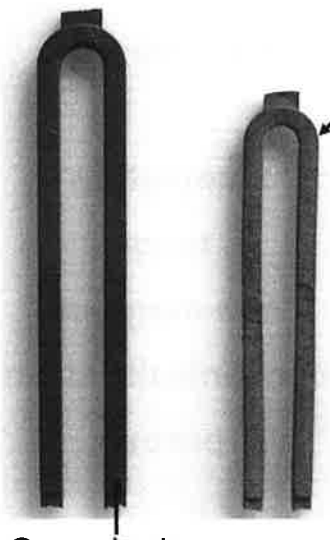
TiN-content ↓
R_{spez} ↑



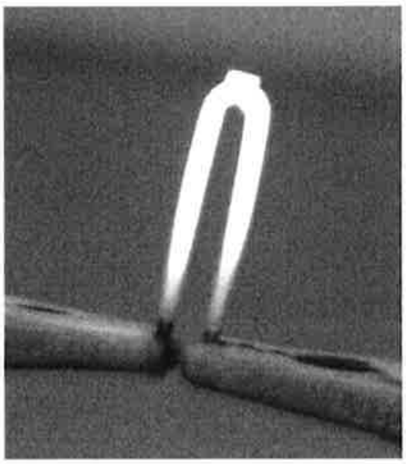
TiN-content ↑
R_{spez} ↓

2C-MicroPIM – Immobile Connections

Adjustment of sintering shrinkage by variation of powder content

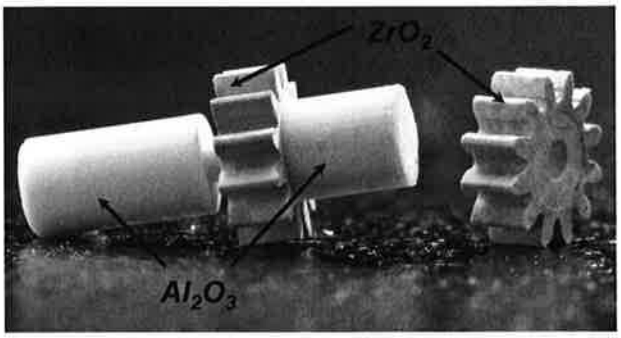


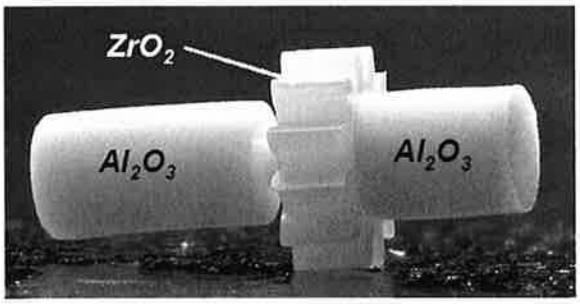
Green body
length = 22 mm
cross section = 1 mm²



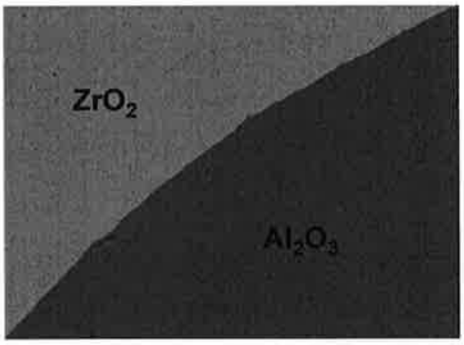
Function test run of ceramic heating element

2C-MicroPIM – Immobile Connections



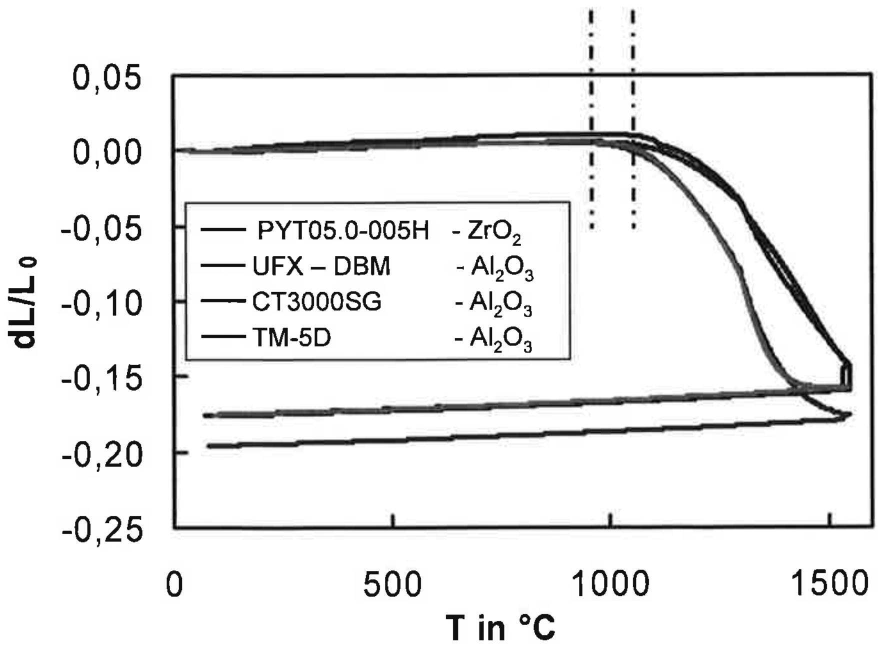


outer diameter (gear wheel):	2.932mm
height (gear wheel):	1mm
hub diameter:	0.65mm
slit tolerance:	0.1mm
shaft diameter:	1.65mm



2C-MicroPIM – Mobile Connections

Adjustment of sintering behaviour

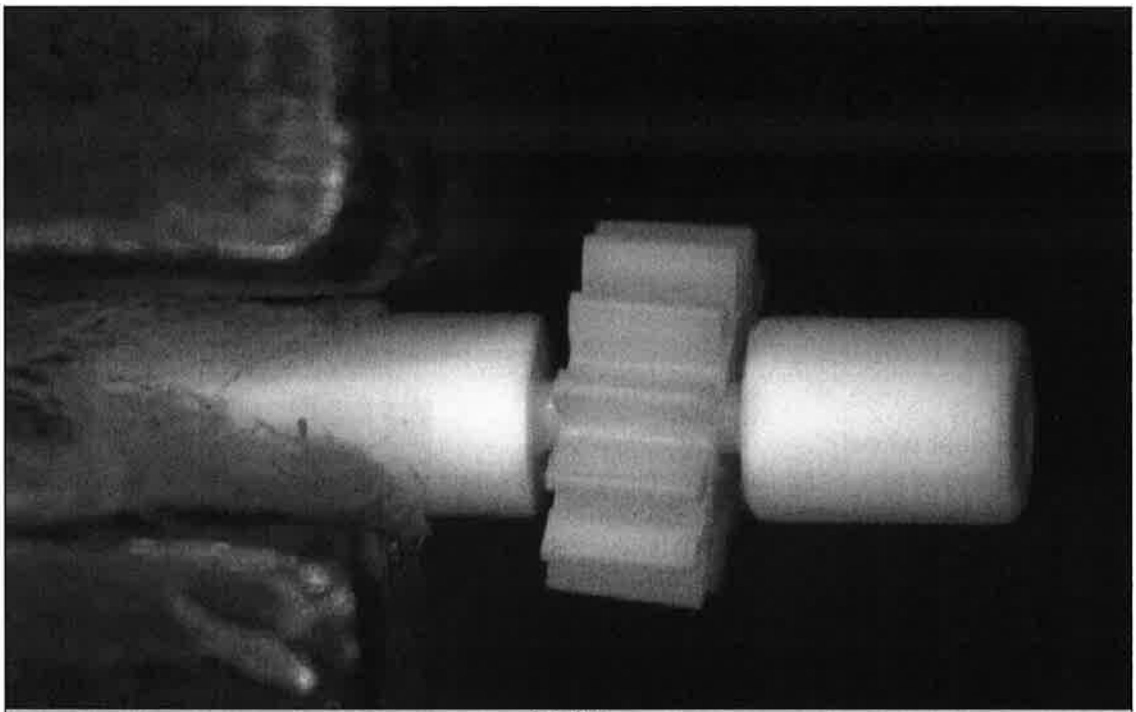


Prior shrinkage of Al_2O_3 (red and green curves) subsequent shrinkage of ZrO_2 (PYT05.0-005H)

→

promising combination for mobile connections

2C-MicroPIM – Mobile Connections



Outlook

- Improvement of dimensional accuracy and surface quality
  e.g. EU-Project „COTECH“, combine µIM + hot embossing
- Enhanced multi-component process variants
  e.g. EU-Projects „COTECH/Multilayer“

2C-µIM New Approaches

Idea:

- series connection of **two 1C-µIM** machines (Micropower®) in row
- rapid **transfer** of 1. shot to 2nd machine by robot
- machines can be **easily connected** and **disconnected**

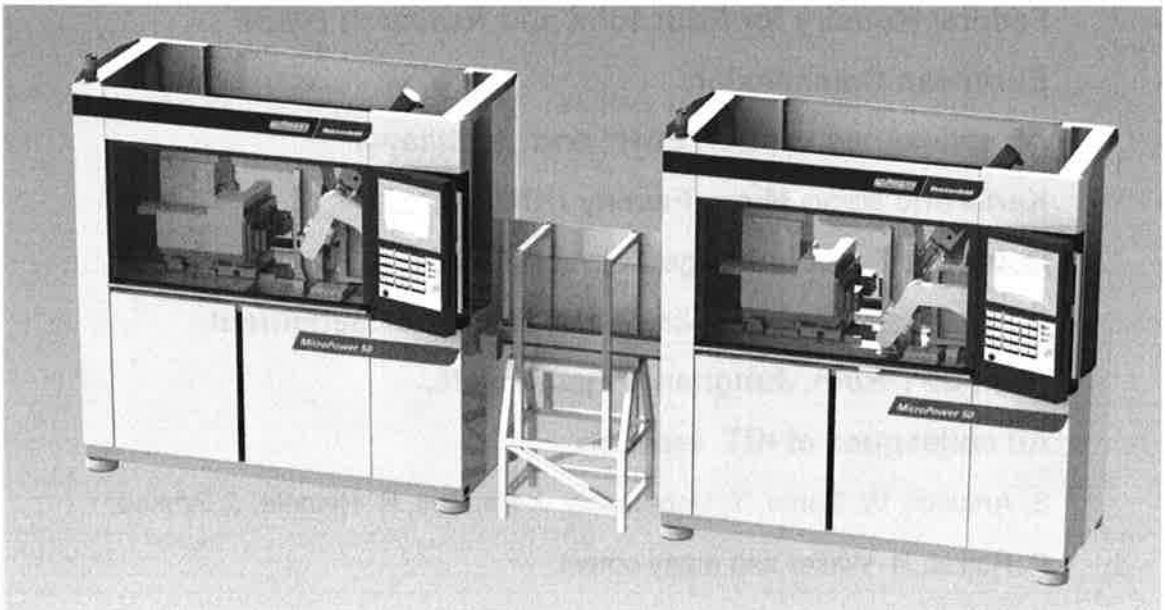
Advantage:

Both machines can be **fully used as 1C-units**
if no order for 2C-parts has to be executed

COTECH

Source: Wittmann Battenfeld, Austria

2C-µIM New Approaches



Source: Wittmann Battenfeld, Austria

Outlook

- Improvement of dimensional accuracy and surface quality
  - e.g. EU-Project „COTECH", combine µIM + hot embossing
- Enhanced multi-component process variants
  - e.g. EU-Projects „COTECH/Multilayer"
- Expanding the range of materials
  - functional materials
  - fine and nano powders etc.
- Special Software for Simulation

Acknowledgment

- Federal Ministry for Education and Research BMBF
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- All colleagues in „COTECH" and „Multilayer"
- Karlsruhe Nano Micro Facility (KNMF)
- Deutsche Forschungsgemeinschaft DFG (SFB 499)
- Companies Arburg, microParts, Wittmann Battenfeld, RKT, SPT Roth, Junghans, Inmatec etc.
- All colleagues at KIT especially

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Thank you !