

Comparative Study of Micro Powder Injection Molding (μ PIM) and Simultaneous Micro Powder Injection Compression Molding (μ PICM)

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Outline of the talk

- I. Introduction and Motivation
- II. Injection Compression Molding
- III. Performing of simultaneous Micro Powder Injection
Compression Molding (μ -PICM)
- IV. Reproduction of micro structures by simultaneous μ -PICM
- V. Investigation of sequential μ -PICM
- VI. Summary and Outlook

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Introduction and Motivation

Advantages of Injection Compression Molding (ICM):

Processing:

- Reduction in injection pressure, clamping force and cycle time
- Uniformly acting holding pressure
- Compensates shrinkage by compressing the melt by clamping movement
- Less material shear

Molded parts:

- Minimization/elimination of sink marks and warpages
- For long-fiber-reinforced thermoplastics: reduction of fiber degradation in parts
- For transparent parts: improvement of dimensional accuracy thus optical properties

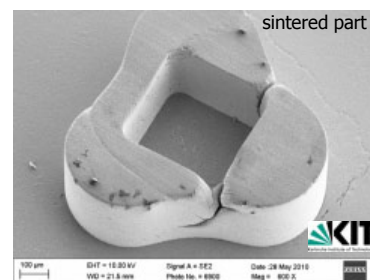
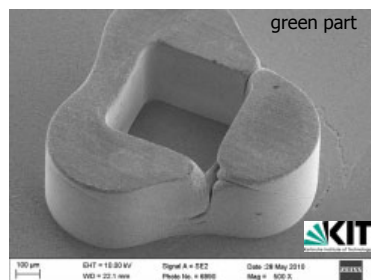
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Introduction and Motivation

Motivation

- Flaws due to incomplete filling at μ -PIM



- Design of the ICM process for powder material and investigation of the influence on accuracy reproduction of micro structure by use of design of experiments (DoE)

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Injection Compression Molding (ICM)

Versions of Injection Compression Molding Process

Coining axis	Main axis
	Secondary axis
	Combined main and secondary axes
Direction of coining	Clamping coining
	Opening coining
	Combined opening/closing coining
Temporal sequence	sequential
	simultaneous

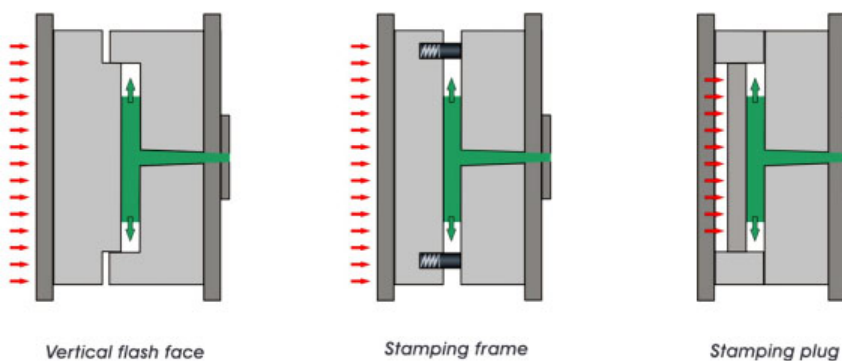
Source: T.Walther, U.Mueller, „Optical parts (2)“
Kunststoffe International 11/2009

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Injection Compression Molding (ICM)

Mold concepts for injection compression molding

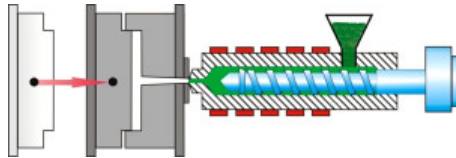


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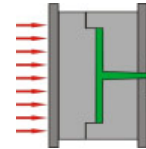
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Injection Compression Molding (ICM)

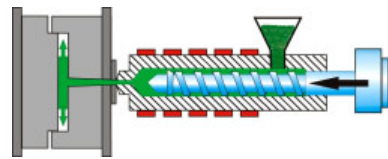
Process cycle of Injection Compression Molding (ICM)



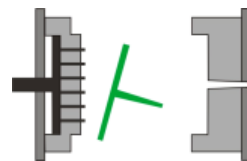
1. Mold moving to compression gap



3. Compression by clamping movement of the machine



2. Melt injection into a cavity (80-90% cavity volume)



4. Cooling, opening and ejection

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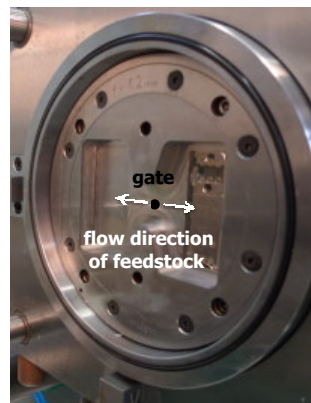
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Performing of Simultaneous Micro Powder Injection Molding (μ -PICM)

- Mold with shearing edges
- Commercial injection molding machine (ARBURG® Allrounder 420C)
- Machine control allows for individual programming of μ -PIM and μ -PICM
- Design of Experiments (DoE): full two-level four-factorial (2^4)

Process parameter	Low level	High level
Compression force [kN]	200	400
Compression speed [mm/s]	1	3
Compression starting time [s] after injection of feedstock	0.5	0.7
Holding time [s]	1	2

Other process parameters	
Tool temperature [°C]	75
Injection speed [mm/s]	95
Hold pressure [bar] for μ -PIM	750
Hold time [s] for μ -PIM	2.2
Cooling time [s]	30

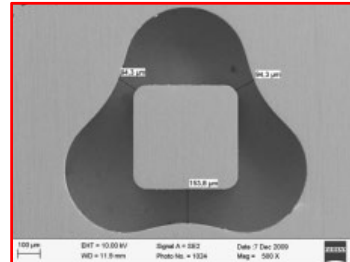
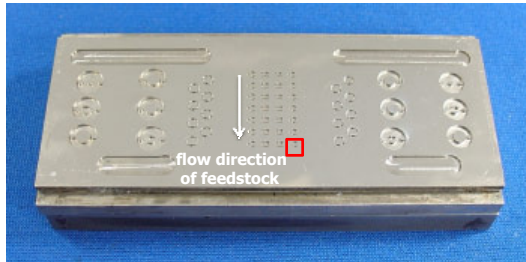


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Performing of Simultaneous Micro Powder Injection Molding (μ -PICM)

- Tool insert with micro structures produced by LIGA (Lithography, Electroplating and Molding)

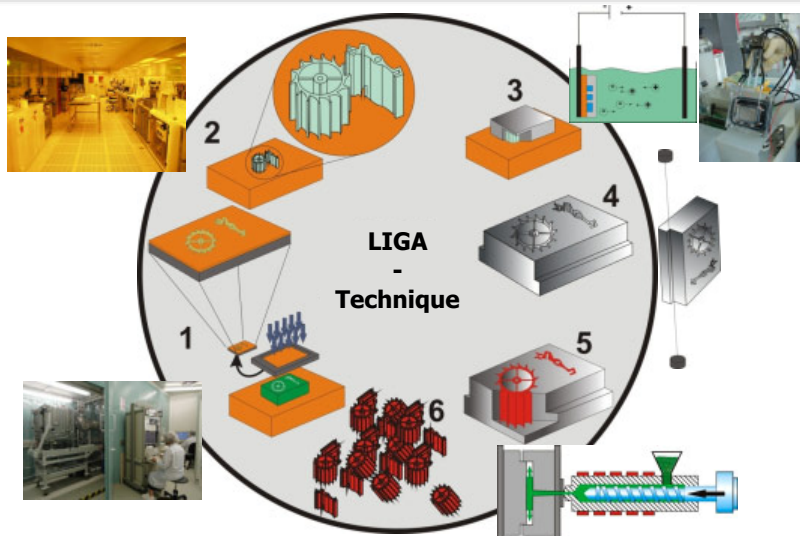


- **Feedstock:** yttria stabilized zirconium powder (TZ-3YS-E) with binder system (Polyethylen, wax, stearic acid)

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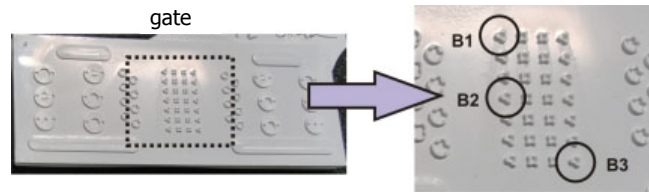
Performing of Simultaneous Micro Powder Injection Molding (μ -PICM)



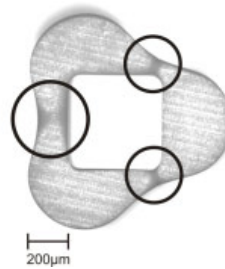
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Performing of Simultaneous Micro Powder Injection Molding (μ -PICM)



- Investigation of replication quality especially in the area with micro structures of high aspect ratio
- Qualitative rating by use of binary evaluation and arithmetic average of each structure
- Influence of the position of micro structure (near and far to the gate)



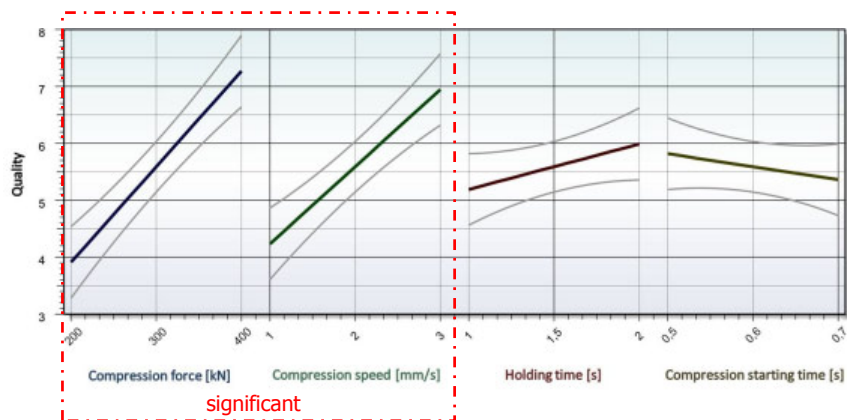
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Reproduction of micro structures

Optimum process parameters of DoE for simultaneous μ -PICM

Compression force [kN]	400
Compression speed [mm/s]	3
Compression starting time [s]	0.5
Holding time [s]	2

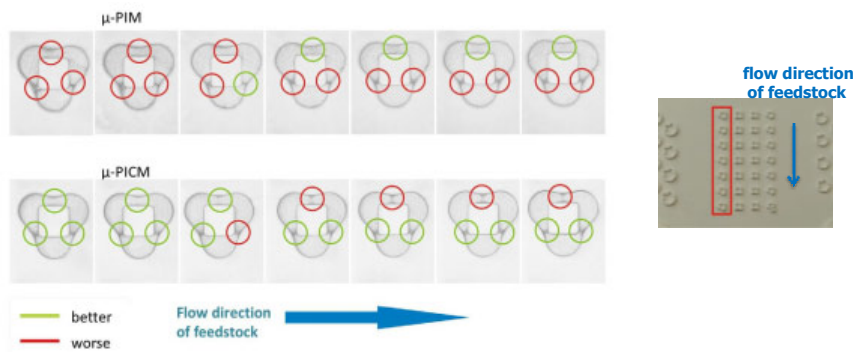


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Reproduction of micro structures

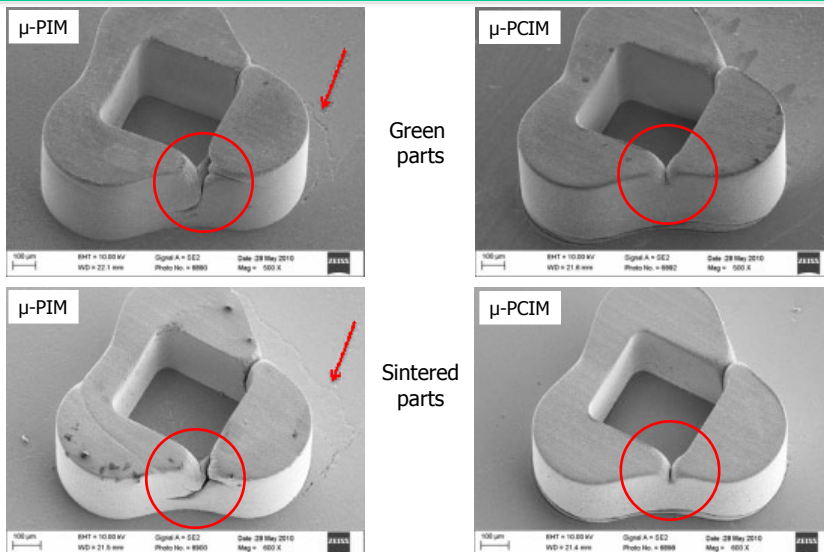
- Comparative analysis between μ -PIM and simultaneous μ -PICM (optimum process parameters) show marginal improvement of the replication
- Increasing of the significant parameters at μ -PICM: compression force (600kN) and compression speed (6mm/s)
- Comparison between μ -PIM and simultaneous μ -PICM:



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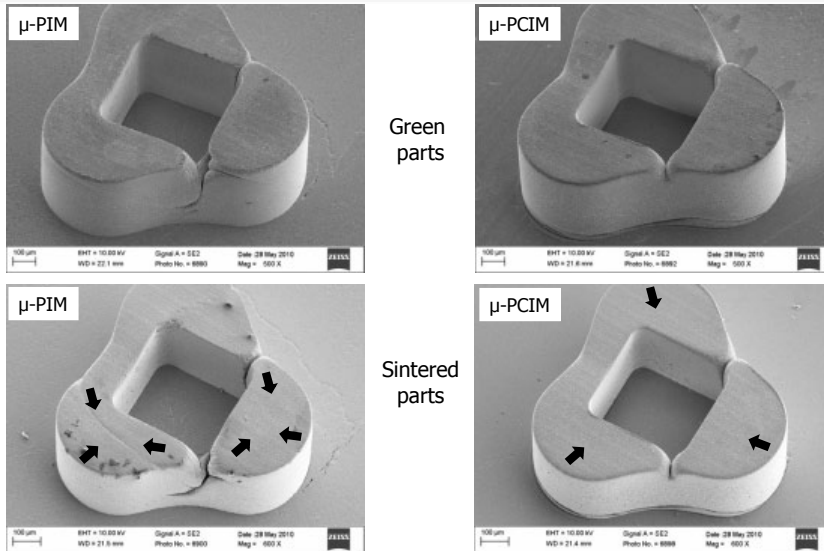
Reproduction of micro structures



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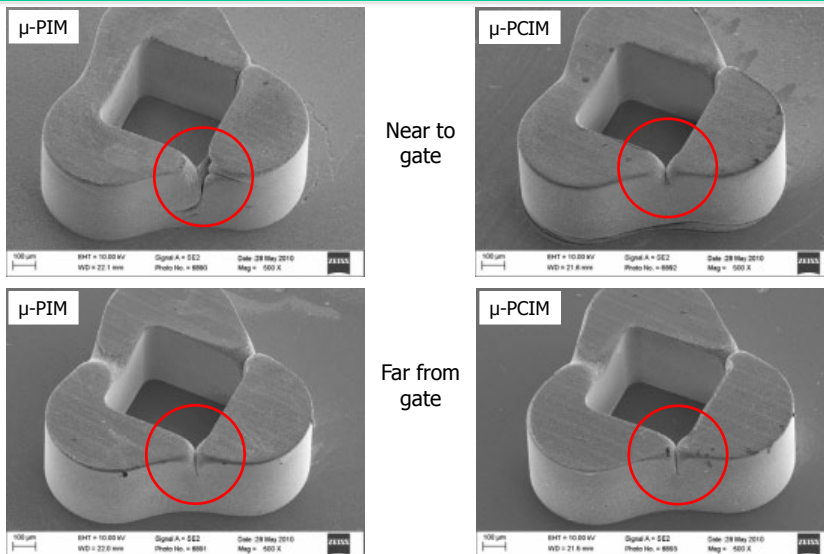
Reproduction of micro structures



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Reproduction of micro structures



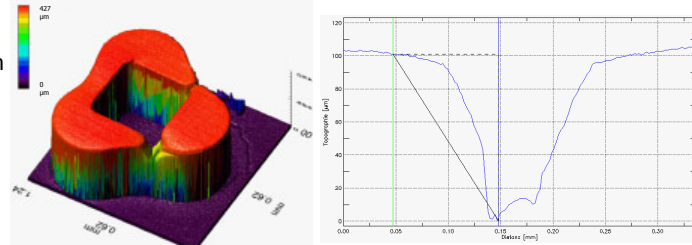
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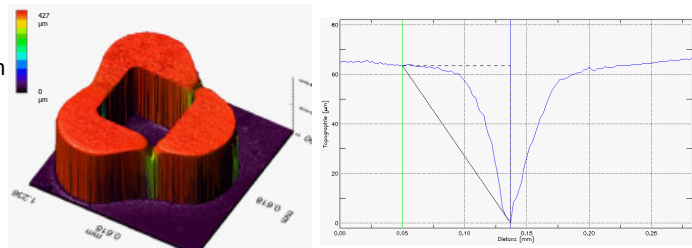
Reproduction of micro structures

- Investigation of the unfilled areas by use of white light interferometer

➤ μ -PIM: 101,1 μm



➤ μ -PICM: 63,6 μm



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Investigation of sequential μ -PICM

- Machine, mold, structured insert and feedstock unchanged
- DoE: full two-level four-factorial (2^4)

Process parameter	Low level	High level
Compression force [kN]	400	600
Compression speed [mm/s]	3	6
Compression gap [mm]	0.6	1.1
Holding time [s]	1	2

Other process parameters

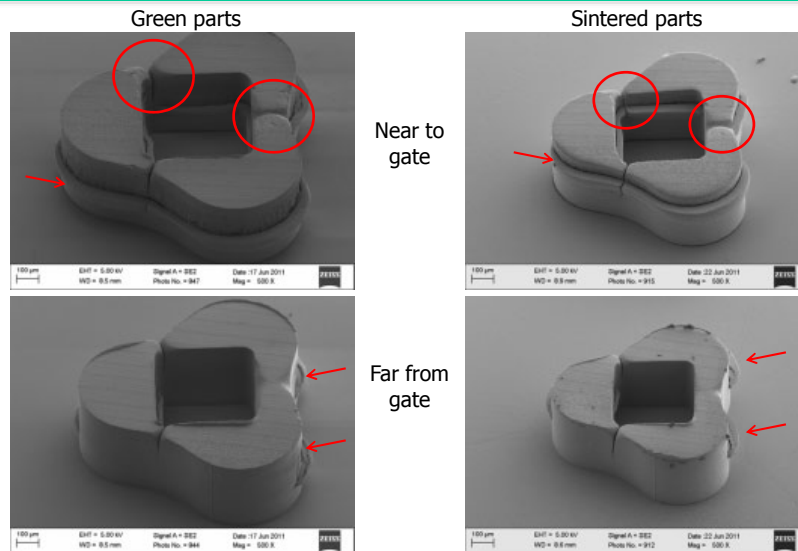
Tool temperature [°C]	75
Injection speed [mm/s]	95
Cooling time [s]	30

- Significant influence: compression force

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Investigation of sequential μ -PICM



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Summary and Outlook

- Successful implementation of the simultaneous μ -PICM
- First significant process parameters were appointed
- Obvious improvement of micro structure near to the gate with μ -PICM
- Future: further optimization of simultaneous μ -PICM (variothermal processing)

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