Comparative Study of Micro Powder Injection Molding (µPIM) and Simultaneous Micro Powder Injection Compression Molding (µPICM)

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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):

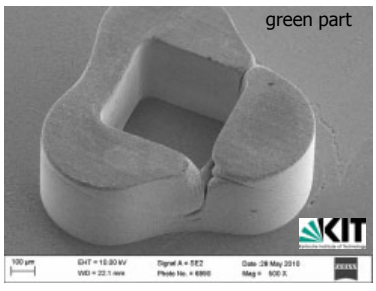
Processing:
- Reduction in injection pressure, clamping force and cycle time
- Uniformly acting holding pressure
- Compensates shrinkage by compressing the melt by clamping movement
- Less material shear

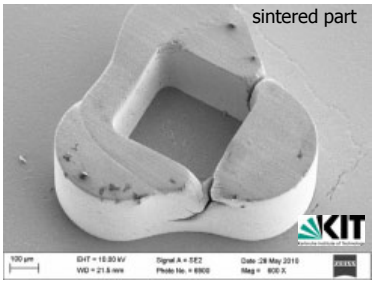
Molded parts:
- Minimization/elimination of sink marks and warpages
- For long-fiber-reinforced thermoplastics: reduction of fiber degradation in parts
- For transparent parts: improvement of dimensional accuracy thus optical properties

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)

Injection Compression Molding (ICM)

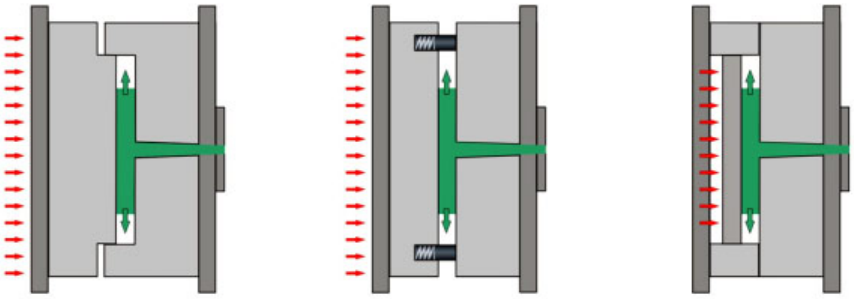
Versions of Injection Compression Molding Process

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

Injection Compression Molding (ICM)

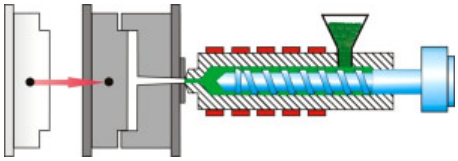
Mold concepts for injection compression molding



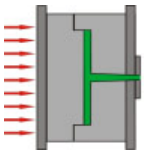
Vertical flash face *Stamping frame* *Stamping plug*

Injection Compression Molding (ICM)

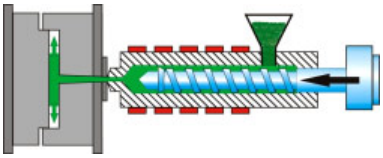
Process cycle of Injection Compression Molding (ICM)



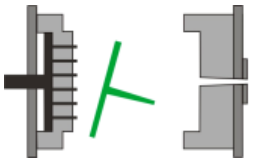
1. Mold moving to compression gap



3. Compression by clamping movement of the machine



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



4. Cooling, opening and ejection

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

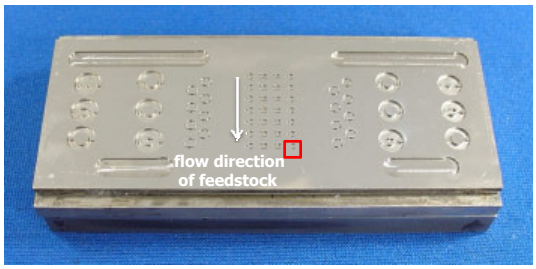
- Design of Experiments (DoE): full two-level four-factorial (2^4)

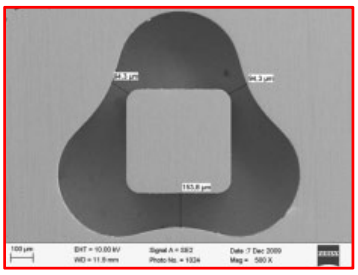
Process parameter	Low level	High level
Compression force [kN]	200	400
Compression speed [mm/s]	1	3
Compression starting time [s] after injection of feedstock	0.5	0.7
Holding time [s]	1	2

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

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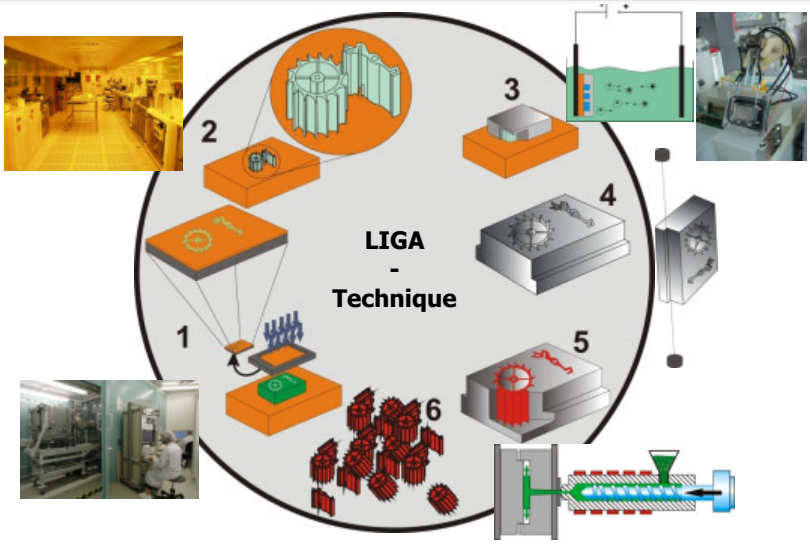
Performing of Simultaneous Micro Powder Injection Molding (µ-PICM)



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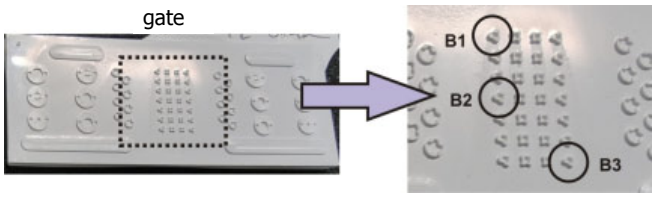
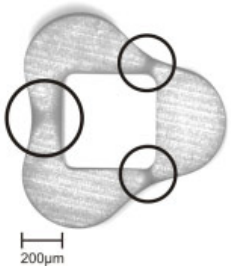
Performing of Simultaneous Micro Powder Injection Molding (µ-PICM)



- 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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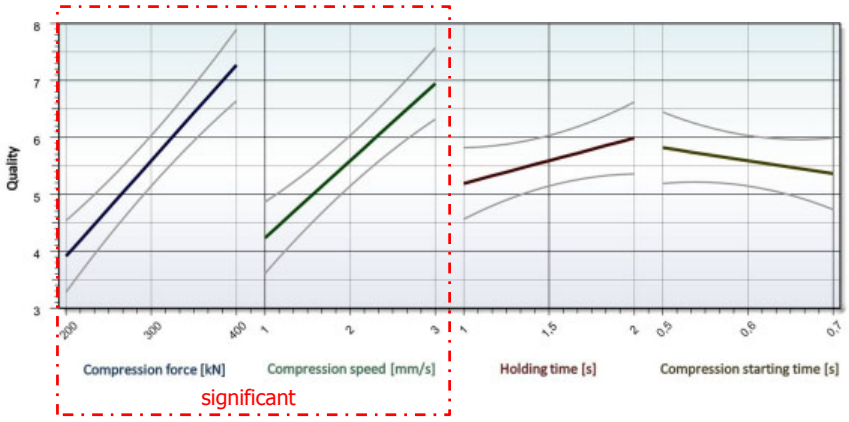
Reproduction of micro structures

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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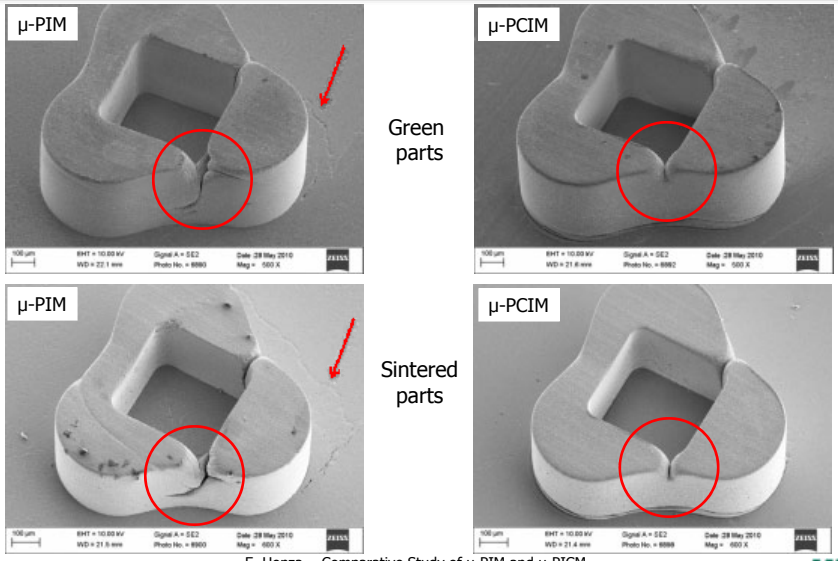
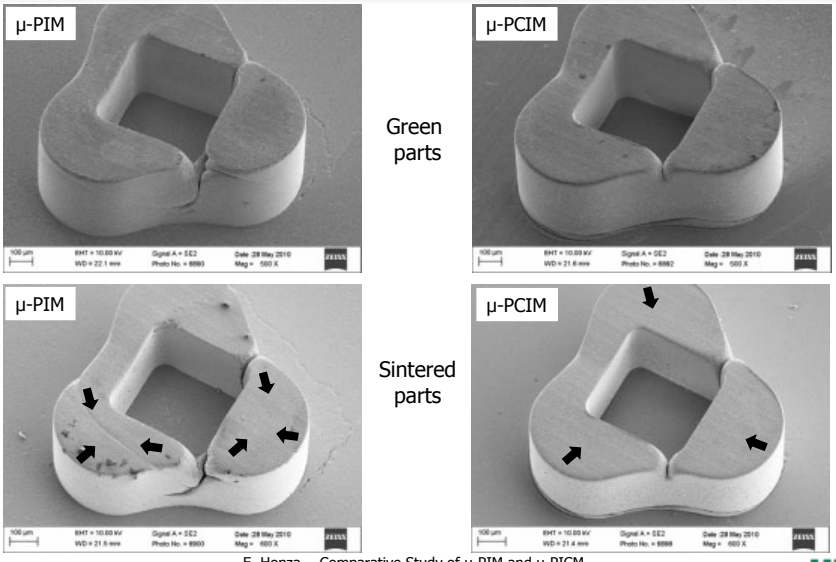
Reproduction of micro structures

- 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:

Reproduction of micro structures



Reproduction of micro structures



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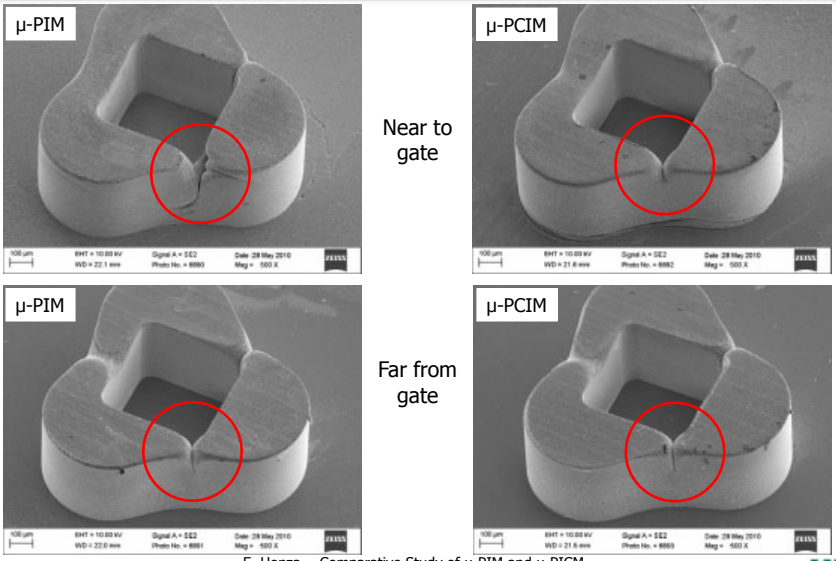
Reproduction of micro structures



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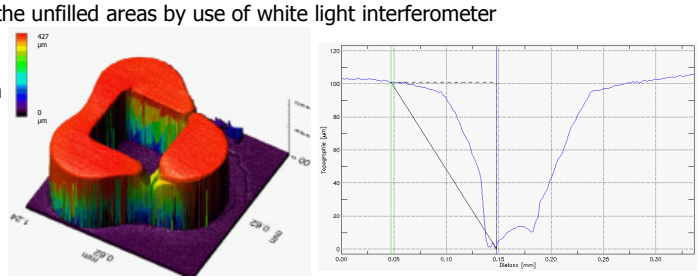
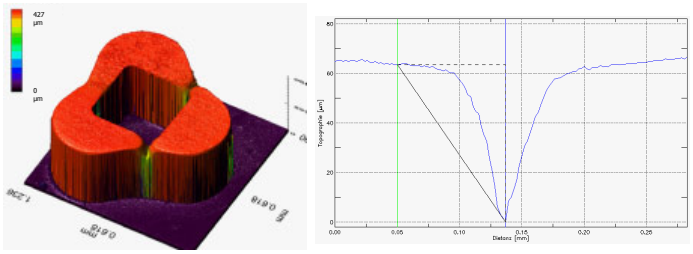
Reproduction of micro structures

- Investigation of the unfilled areas by use of white light interferometer
- µ-PIM: 101,1 µm



- µ-PICM: 63,6 µm



Investigation of sequential µ-PICM

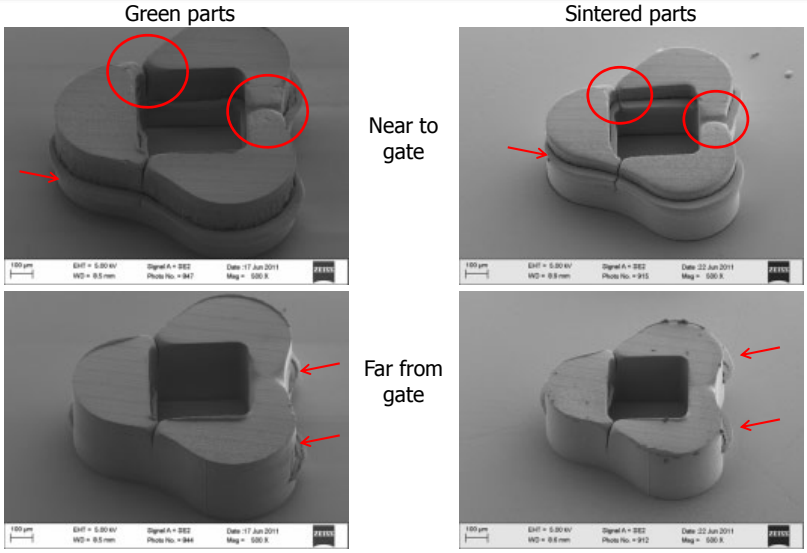
- Machine, mold, structured insert and feedstock unchanged
- DoE: full two-level four-factorial (2^4)

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

Investigation of sequential µ-PICM



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)