In-mold Labeling
Micro Powder Injection Molding:
Large Scale Production of
Micro Structured Two-component Parts

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Outline of the talk

I. Introduction and Motivation
II. In-mold Labeling Micro Powder Injection Molding (IML-µ-PIM)
III. Performing of IML-µ-PIM
IV. Reproduction of micro structures
V. Debinding and Sintering
VI. Summary and Outlook
Advantages of multi component shaping methods:

- Reduction of handling and assembly expenditure
- Reduction of plant costs
- Combination of different materials, for example:
  - multi colour products
  - electrical conductivity/electrical insulation
  - hardness/toughness
  - magnetic/non-magnetic
  - fixed/movable connection
- Many possible applications in different sectors (bio-/medical, IT, micro system technology, etc.)
Introduction and Motivation

Combination of IML Technique with Powder Injection Moulding (PIM)

Possible application of colored and/or structured ceramic IML-parts:

- For additional structuring and/or refining of surface
- Haptic reception, resistant to abrasion, durable parts
- Nano-particles applied on the structured surface:
  - better contour accuracy,
  - higher surface quality,
  - functional properties etc.

In-mold Labeling Micro Powder Injection Molding

Production of tapes and feedstock

Requirements for multi component ceramic parts:

- Compatible binder systems with comparable thermal expansion behaviour
- Selected powders with similar sintering behaviour:
  - Comparable absolute shrinkage values and rates during sintering
  - Comparable sintering temperatures and gas atmosphere
In-mold Labeling Micro Powder Injection Molding

Process chain contains several challenging fabrication procedures:

- Tape
- Stamping tape
- Insert tape
- IML
- Removal
- Quality Control I

Post-treatment:

- Quality Control III
- Debinding Sintering
- Magazination
- Quality Control II
- Stamping IML-part

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Performing of IML-µ-PIM

**Tool concept** combines Powder Injection Molding (PIM) with micro replication features (e.g. variothermic process control) and IML-process

Features of the tool:

1. Fixing of tapes/labels with blank holders
2. Vacuum system
3. Variation of tape thickness between 0.1 and 1mm
4. Variation of mould insert position (parallel & cross to flow direction)

☑ In addition: three different thicknesses of the parts (1.5 mm, 1.9 mm and 2.4 mm)

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Performing of IML-µ-PIM

- Filling study (PE-tapes and PE as molding compound)
  
  Good results without defects and good analogy to pure injection molding

- ZrO₂ tapes (thickness: 300µm) and ZrO₂ feedstock

Ceramic IML- parts with size of 80x80mm² and thickness of approx. 1.8 mm

Performing of IML-µ-PIM

The selection of appropriate process parameters is critical for the realization of defect-free IML-µ-PIM parts

- Injection speed: with low injection speed deformation of parts and air entrapment between tape and feedstock
Performing of IML-µ-PIM

**Tool temperature:**

- Increase of the tool temperature results in adhesion between tool and tape and in (partial) damage of the parts
- Decrease of the tool temperature results in better planarity of parts

Reproduction of micro structure

**Micro structured tool insert**
Reproduction of micro structure

Investigation of the influence of process parameters on the reproduction accuracy:

<table>
<thead>
<tr>
<th>Process parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool temperature [°C]</td>
<td>40-50-60</td>
</tr>
<tr>
<td>Injection speed [mm/s]</td>
<td>48-52-56</td>
</tr>
<tr>
<td>Holding pressure [bar]</td>
<td>430-550-650-850</td>
</tr>
</tbody>
</table>

Measuring of reproduction accuracy:
- Near to the gate
- Far from the gate
- Middle of structure

Reproduction of micro structure

Measuring of reproduction accuracy:
- Near to the gate good reproduction
- Decline of structure accuracy with distance from the gate
Reproduction of micro structure

Flow behavior of the feedstock and the behavior of the tape especially away from the gate identifiable

Debinding and Sintering

Preparation of debinding routes:

- Debinding process quite often combination of solvent and thermal debinding
- Thermal analysis (DSC, TG, DTA) provide the necessary data for several binder components

The final debinding route has to consider the thermal behaviour of the components
Debinding and Sintering

DTA investigations → Search for suitable process parameters:

- Melting point of wax between 50 to 70 °C (A) → low heating rates
- At a temperature of approx. 150 °C the decomposition of the remaining binder components starts (B) → increasing of heating rates

Debinding and Sintering

Sintering routes:

- Starting with materials of similar shrinkages at comparable temperatures → avoid the deformation of parts

- Starting with materials of similar thermal behaviour (thermal expansion coefficient) → production of crack free multi component parts
Debinding and Sintering

Shrinkage of structure ~ 21%

Summary and Outlook

- Realisation of IML-µ-IML technique using powder materials is possible
- Combination of materials with different properties
- Adjustment of materials essential
- Further investigations of process parameters and of accurate reproduction of complex structures

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