Micro and Precision Powder Injection Molding
- Materials, Variants, Opportunities

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Contents

- Powder Injection Molding in micro dimensions (MicroPIM)
- Accuracy considerations on MicroPIM
- PIM of tungsten and tungsten-alloys
- Micro Inmold-labeling using PIM-Feedstocks
- Outlook
Micro System Technology

Source: Yole Development, March 2013

MEMS market forecast 2012-2018 value (in M$)

- Others
- Oscillators
- RF MEMS
- Microdispensers (microfluidics)
- Microfluidics for IVD
- Microfluidics for research
- Other optical MEMS
- Projection systems
- Micro displays
- PIR & thermopiles
- Microbolometers
- Inertial combos
- Digital compass
- Gyroscopes
- Accelerometers
- Microphones
- Pressure sensors
- Inkjet sensors

CAGR 13%
MicroPIM

Capillary for fine pitch bonding
tip-Ø=45µm, hole-Ø=19µm
SPT Roth Ltd., CH

Scientific application: liquid jet nozzles for CFEL
collaborative project between DESY and KIT
Accuracy in (Micro-)PIM

SoA: (± 0.05%) ± 0.1% - ± 0.5%

Determination of explanatory variables, e.g. tool/runner concept

Design and construction of experimental tool
- 2 movable pistons
- position of injection gates variable
- vacuum system
- pressure sensor
- 6 heating elements near to cavity

Three ways of process conduct: Injection
- into empty cavity
- against pressureless pistons
- against pressurized pistons
Accuracy in (Micro-)PIM
Accuracy in (Micro-)PIM

Sample for initial trials
Ø = 2.015mm

gate position: dye side / middle
piston pressure: 5.8% / 19.5% of P_{\text{max, motor}}

Two feedstocks:

- ZrO$_2$ Tosoh TZ-3YS-E
- 17-4PH Osprey 1.4542
Accuracy in (Micro-)PIM

→ best accuracy for nearly zero counterpressure i.e. quasi-balanced force state
→ standard deviation increases with distance to back pressure insertion
Accuracy in (Micro-)PIM

Green bodies

![Graph showing diameter and standard deviation vs. powder loading](image-url)
Accuracy in (Micro-)PIM

Sintered parts

Accuracy in (Micro-)PIM

Sintered parts

Accuracy in (Micro-)PIM

Sintered parts
### Micro Injection Molding – General Data

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>Plastics</td>
<td>10</td>
<td>≤0.08</td>
<td>&gt;20 (200*)</td>
<td>0.05</td>
<td>0.05 / &lt;0.05</td>
<td>Thermoplastics, TPE</td>
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<tr>
<td>Metals</td>
<td>50</td>
<td>10</td>
<td>&gt;10</td>
<td>&lt; 0.5</td>
<td>7 / 0.8</td>
<td>17-4PH, 316L, Cu, W, W-alloys</td>
</tr>
<tr>
<td>Ceramics</td>
<td>&lt;10</td>
<td>&lt;3</td>
<td>&lt;15</td>
<td>(0.1***) / 0.3</td>
<td>&lt;3 / &lt;0.3</td>
<td>ZrO(_2), Al(_2)O(_3), ZTA, Al(_2)O(_3)/TiN, Si(_3)N(_4)</td>
</tr>
</tbody>
</table>

* flow length to wall thickness ratio  
** depending on mold insert  
*** after thorough process optimization
Tungsten PIM (WPIM)

Divertor components for FUSION reactors

DEMO reactor:
- nearly 300,000 devices
- lifetime nearly 2 years

1 Finger-module:
- 3 main parts
- 2-3 materials
- 2 brazed joints
- assembly …
2-Component Tungsten PIM (2C-WPIM)

Needed: Joining method for thimble and tile

⇒ production of both parts as one unit in one cycle
⇒ effective fabrication by reduced assembly efforts
⇒ saving of brazing steps
New fully automatic 2C-WPIM tool

Ejection side

Nozzle side
2C-WPIM

W + W2La$_2$O$_3$

AES Map
black: La$_2$O$_3$
red: W

Only presintering!
Tungsten PIM (WPIM)

Needed: really heavy components

green body

sintered part
Micro Powder Inmold-labeling (IML-MicroPIM)

- combining the advantages of two shaping methods …

EU Project No. FP7-NMP4-2007-214122
Micro Powder Inmold-labeling

PIM-Feedstock containing Powder 1

foil/film containing Powder 2

Powder 2: functional or nano-particles applied on the structured surface
Production of green bodies

- PIM green body
- Tape with scripture relief
- Fine-sized ZrO₂
- PIM body
Investigation of samples

green body

c. 53Vol% ZrO₂
70nm

c. 50Vol% ZrO₂
40nm

c. 50Vol% ZrO₂
440nm
Outlook

- Enhancing **technical performance**
  
  improve dimensional accuracy and surface quality
  
  larger variety of materials, e.g. nanopowders
  
  improve simulation/predictability

- Extended use of **multi-component** variants
  
  micro inmold-labelling using nanopowders
  
  two-component micro injection moulding
  
  sinter-joining of PIM green bodies
Outlook

- Hybridization of micro processing technologies
  3D-MID and variants

PIM + Additive Manufacturing

1. Micro PIM
2. 3D inkjet printing
3. Debinding
4. Sintering

Highest geometrical degree of freedom ↔ maintain mass fabrication capability
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