Rapid Hybrid Tooling based on CNC- and µEDM-Milling to fabricate Lab-on-a-Chip Systems

T. Hösel¹, R. Jurischka¹, A. Schoth¹, C. Baggi², R. Gallera², C. Müller¹, H. Reinecke¹

¹Department of Microsystems Engineering IMTEK, Laboratory for Process Technology, University of Freiburg, 79110 Freiburg, Germany

²Sarix SA, Micro EDM Technology, 6616 Losone, Switzerland
Motivation

Requirements for Tools and Tooling Technologies

Tooling Technologies

Hybrid Tooling

Summary
Requirements

- Micro fluidic devices combined with macroscopic reservoirs
- Polymer based
- High accuracy

Fabrication

- Fast development of prototypes and small series fabrication
- Low cost products and disposables

Cost effective and fast Tooling Technology for polymer replication
Requirements for Tools

- Made of hard metals, e.g. tool steel
- Chemical resistance
- High durability
- Low wear
- High strength
Requirements for Tooling Technologies

Fabrication of macro structures
- CNC-Milling: fast, precise, direct 3D-structuring
- EDM-Sinking: fast, batch, electrode wear above 3%

Fabrication of micro structures
- ECM: precise, complex process technology
- μEDM-Milling: high accuracy, direct 3D-structuring
Cooperation with Sarix SA, Switzerland

- Work table size: 750 x 300 mm²
- Travel Z axis: 200 mm
- Precision of positioning: ± 2 µm
- Resolution: 0.1 µm
- Micro fine pulse shape generator
- Integrated wire electric discharge grinding unit to grind electrodes down to a diameter of 5 µm
Wire Electric Discharge Grinding Unit

- Integrated laser measuring system
- Electrode measurement accuracy: ± 0.15 µm
- Automatic electrode profile control
- µEDM electrodes shaping with C axis
CNC-Milling

- 3D machining
- One step structuring of steel
- Aspect ratio: 10 - 100
- High removal rate

- Min. structures above 100 μm
- Burrs

μEDM-Milling

- 3D machining
- One step structuring of steel
- No process forces
- Min. structures down to 15 μm
- Surface roughness

- Aspect ratio: up to 10
- Low removal rate

No single Tooling Technology for mould inserts with macro AND micro structures
Combination of Tooling Technologies

- Tooling Technology for mould inserts with micro and macro structures
- Reduction of process time
- High achievable quality
- High accuracy
- High reproducibility
Step 1: CNC-Milling
- Macro structures

Step 2: µEDM-Milling
- Micro structures
- Surface finishing
Hybrid Tooling - Typical values

<table>
<thead>
<tr>
<th></th>
<th>Macro structures</th>
<th>Micro structures</th>
<th>Process times</th>
</tr>
</thead>
<tbody>
<tr>
<td>height</td>
<td>800 µm</td>
<td>100 µm</td>
<td>CNC-milling</td>
</tr>
<tr>
<td>taper angle</td>
<td>5°</td>
<td>0.8°</td>
<td>3 h</td>
</tr>
<tr>
<td>roughness Ra</td>
<td>70 nm</td>
<td>70 nm</td>
<td>µEDM-milling</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17 h</td>
</tr>
<tr>
<td>min. width</td>
<td></td>
<td></td>
<td>total</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20 h</td>
</tr>
</tbody>
</table>

- No burrs
- High accuracy
- Smooth sidewalls

Detail of mould insert (SEM)
Moulding in COC

- Microstructures with high aspect ratio ~ 6
- Tested up to 8000 cycles
- Typical process time for IM = 35 s

Detail of moulding (SEM)  Cross section of micro channels
Hybrid Tooling for Prototyping and Mass Fabrication

- Rapid and direct structuring of tool steel
- Mould inserts with micro and macro structures without burrs and with high surface quality
- Prototype and final product with same properties
- Rapid design cycles leads to reduction of development time
Thank you for your attention!