3D Printing for MicroFluidics Manufacturing

Innovative Manufacturing of Microfluidics

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3D Printing for MicroFluidics Manufacturing

OUTLINE

• Introduction 3D Printing of Micro Fluidics

• 3D Printing for Microfluidics

• 3D Printing as a Manufacturing Technology

• MFManufacuring Project

• Conclusion
Introduction 3D Printing of Micro Fluidics


Source: Scopus, December 1, 2015
# Introduction 3D Printing of Micro Fluidics

<table>
<thead>
<tr>
<th>3D Printing Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inkjet printing</td>
<td>Cheap</td>
<td>3D Build difficult</td>
</tr>
<tr>
<td><strong>SLA (Stereo Lithogr. A.)</strong></td>
<td><strong>High Accuracy</strong></td>
<td><strong>Photo curing</strong></td>
</tr>
<tr>
<td>Laser Direct Writing</td>
<td>Single Cell</td>
<td>No structural support</td>
</tr>
<tr>
<td>Direct Writing</td>
<td>High Accuracy</td>
<td>Cell unfriendly</td>
</tr>
<tr>
<td>Melt Extrusion (FDM)</td>
<td>Simple</td>
<td>High temperature</td>
</tr>
<tr>
<td>SLS (Selective Laser .)</td>
<td></td>
<td>Cell unfriendly</td>
</tr>
<tr>
<td>Robotic Dispensing</td>
<td>Multi Material</td>
<td>Low accuracy</td>
</tr>
<tr>
<td>Bio Laser Printing</td>
<td>Accuracy / Speed</td>
<td>3D Build difficult</td>
</tr>
<tr>
<td>Robotic Assembly</td>
<td>No Heat / Reaction</td>
<td>Expensive Equipment</td>
</tr>
</tbody>
</table>

F.P.W. Mechels, Additive Manufacturing of Tissue and Organs, Progress in Polymer Science 37 (2012) 1079-1104
Introduction 3D Printing of Micro Fluidics

Principle of VAT polymerisation

- Glass
- (blue) light curable resin
- Release layer
- Electronic semi-product
- Cured Resin Layers
- Product carrier
- DLP Projector
Introduction 3D Printing of Micro Fluidics

Principle of VAT polymerisation

Glass

(white) light curable resin

Release layer

Electronic semi-product

DLP Projector

Cured Resin Layers

Product carrier
3D Printing for Microfluidics: Printed Stenosis
3D Printing for Microfluidics: Printed micro Villi

3D Printed microVilli for Gut on a Chip in R11 Material, Printed By TNO, 2015
3D Printing for Microfluidics: Printed micro Villi

3D Printed microVilli for Gut on a Chip with Coca2 cells, BIOC material, Printed By TNO, 2015
3D Printing for Microfluidics: Vascular System
3D Printing for Microfluidics: Organ on a Chip

Cancer on a Chip Well Plate, First Prototype, BIOC material, Printed By TNO, 2015
3D Printing for Microfluidics: Organ on a Chip
3D Printing for Microfluidics: Serpentine Mixer

1 ~ 270 micron
2 ~ 450 micron
3 ~ 360 micron
4 ~ 470 micron
3D Printing for Microfluidics: Serpentine Mixer

1 ~ 570 micron
2 ~ 450 micron
3 ~ 450 micron
4 ~ 515 micron
4 ~ 415 micron
3D Printing for Microfluidics: Serpentine Mixer

REYNOLDS DEPENDENCE

Model: VOF sharp interface
\[v_1, v_2 = 2.1 \times 10^{-5}\]
\[\mu_2, \mu_2 = 0.1\]
\[Re << 1\]

Almost no mixing occurs

Model: VOF sharp interface
\[v_1, v_2 = 1.5\]
\[\mu_2, \mu_2 = 0.1\]
\[Re = 10\]
3D Printing for Microfluidics: Multiple Functions

Integrated Serpentine Mixer and Tesla Valve, BIOC material, Printed By TNO, 2015
3D Printing for Microfluidics: Multiple Functions

Serpentine Mixer and Tesla Valve as Modular Building Block, BIOC material, Printed By TNO, 2015
# 3D Printing as a Manufacturing Technology

<table>
<thead>
<tr>
<th>Company</th>
<th>XY (μm)</th>
<th>Z (μm)</th>
<th>Biocomp.</th>
<th>Price($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EnvisonTEC</td>
<td>16</td>
<td>15</td>
<td>Yes</td>
<td>100.000</td>
</tr>
<tr>
<td>Digital Wax</td>
<td>-</td>
<td>10</td>
<td>Yes</td>
<td>100.000</td>
</tr>
<tr>
<td>FormLabs</td>
<td>300</td>
<td>25</td>
<td>No</td>
<td>2.000</td>
</tr>
<tr>
<td>B9 Creator</td>
<td>50</td>
<td>6.35</td>
<td>No</td>
<td>2.400</td>
</tr>
</tbody>
</table>

**VAT Equipment Developed by TNO**

<table>
<thead>
<tr>
<th>Company</th>
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<th>Z (μm)</th>
<th>Biocomp.</th>
<th>Price($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid Shape</td>
<td>25</td>
<td>25</td>
<td>Yes</td>
<td>25.000</td>
</tr>
<tr>
<td>Lepus Next Gen</td>
<td>20</td>
<td>20</td>
<td>Yes</td>
<td>Development</td>
</tr>
</tbody>
</table>

After: P. Neil, Advances in three-dimensional rapid prototyping of microfluidic devices for biological applications, 2015
3D Printing as a Manufacturing Technology

Printvaley Machine: Third Industrial Revolution
3D Printing as a Manufacturing Technology

Hyproline: Hybrid AM production, Integrated Assembly, cycle time < 60 s

TNO Hyproline 3D Printing Machine, 2015
3D Printing as a Manufacturing Technology
3D Printing as a Manufacturing Technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLIP</td>
<td>6½ Minutes</td>
</tr>
<tr>
<td>Polyjet</td>
<td>3 Hours</td>
</tr>
<tr>
<td>SLS</td>
<td>3½ Hours</td>
</tr>
<tr>
<td>SLA</td>
<td>11½ Hours</td>
</tr>
</tbody>
</table>

* Based on 3rd party tests commissioned by Carbon3D to compare CLIP against a leading commercial printer in each technology category.
3D Printing as a Manufacturing Technology

Nexa 3D: 25 mm in height per 3 minutes

Nexa3D develops fast LSPc resin NX1 3D printer – prints up to a centimeter per minute, 2015
3D Printing as a Manufacturing Technology

Lepus Next Gen: Fast, High Resolution and Large build platform (A4)
3D Printing as a Manufacturing Technology
3D Printing as a Manufacturing Technology

Euromold, Launch of the TNO Lepus Next Gen printer, 2014
MFManufacturing Project

Build microfluidic demonstrators based upon technology building blocks that can be supplied by different technology providers
MFManufacturing Project

Dimensions and port positions of the serpentine mixer building block at standardized positions

To make microfluidic successful, printed or otherwise, we need microfluidic standards!
3D Printing for MicroFluidics Manufacturing

CONCLUSION

- Introduction 3D Printing of Micro Fluidics
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MicroFluidic Manufacturing

MFM

Companies involved:
- Micronit
- AXXICON
- MESA+
- TNO
- PHILIPS
- MEDI METRICS
- FLUI gent
- APix
- EVEON
- PMB
- CEA
- LETI
- TOPPAN
- Stiplastics
- FOGALE
- Tronics
- National Physical Laboratory