Design for Microfluidic Device Manufacture Guidelines

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With contributions from the following members of the MFS Microfluidics consortium: Dolomite, IMT, Micronit, and EV group and Sony DADC

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Context:
The Mission of the Microfluidics Consortium (http://www.cfbi.com/microfluidics.htm) is to grow the market for microfluidics enabled products and services. With members from all parts of the value chain from materials to end users and covering Europe and the USA the consortium has deep insight into the challenges and opportunities which the ‘microfluidics industry’ faces.

One challenge is that the process of moving from a research prototype device to a production device takes too long and is too expensive. This is the case for a wide variety of materials and manufacturing processes. An important part of the challenge is that often researchers are designing devices for the first time and stumble over multiple problems that an experienced designer might be able to avoid. The flip side of the same argument is that potential manufacturers are often frustrated when prototype designs presented to them which are difficult, inappropriate or even impossible to manufacture in large volumes at low cost.

Objectives of this paper:
This White Paper is an attempt initiated by the Microfluidics Consortium to improve the situation. It is made available for free to researchers and developers around the world who are contemplating the creation of prototype devices containing microfluidics. Its purpose is to make developers aware of some of the “design for manufacture” issues which, if dealt with early, can improve the chances of their device being manufacturable, economically and reliability wise.

Positioning of this paper:
This paper is “application agnostic” – it should be relevant to people working in: Diagnostics, High Throughput Screening, Sample Preparation, Genomics, PCR, Circulating Tumour Cells, Regenerative Medicine, Flow Chemistry, Environmental, Food and Homeland Security Sensing .. and beyond!

This paper is also “materials agnostic” – we recognise that microfluidic devices can be realised in PDMA, Polycarbonate, Flexible web, Glass, Silicon, Metal and paper. Different members of the consortium specialize in different materials and have contributed “boxes” representing design for manufacture with different materials. We do, however, see that certain materials, processes are better suited to particular classes of product and application. With this in mind the “Decision Tree” in diagram 1 is designed to guide new developers to choices which suit their plans, time-scales, budgets as well as technical needs.

Furthermore this paper is “manufacturing process agnostic” – recognising again that processes such as: etching, lithography, injection moulding, hot embossing, 3D printing and even modified Xerography are valid routes to manufacture of microfluidics devices. Again, members of the consortium have contributed “boxes” highlighting design for manufacture needs associated with different processes and links to further reading.

Our vision is that newcomers to research and development using microfluidics – probably wishing to use PDMS for rapid prototyping – will spend a little time considering with what material and with what manufacturing process their prototype device might be realised. They will then look at the relevant boxes and take the design guidelines into account as they are choosing formats, geometries etc. for their devices.

While members of the consortium are always interested in talking with players wishing to scale up manufacturing of their devices, it is helpful for both sides if the “basics” are already covered so that expensive learning and re-design processes can be avoided.
It is intended that this will be a “living document” .. updated as new materials and manufacturing techniques emerge. Members of the Microfluidics consortium manage the editorial and are keen on feedback regarding how the document might be improved.

Note: This document does not guarantee IP freedom to operate! There is a complex landscape of patents around microfluidics devices so it is up to you to check whether you need a licence!

**Material selection:**

It is possible that readers know exactly what material or process they are interested in or forced to use – in which case they should “fast forward” to the boxes below which interest them. For those who are less clear (or have more operational freedom) the table below is designed to guide readers towards appropriate fundamental choices. This is intended as rough guidance – there will be special cases which need to be looked at more closely before decisions are made!

Be aware, preferably the material chosen to do your prototyping should be the same as the one intended to be the material used in the final product. Otherwise a costly and time consuming redesign is likely.

The different candidate construction materials for microfluidics differ widely in properties. Endless discussions are possible about their relative strengths and weaknesses.

The decision support charts A and B give a first pass indication of the relative merits of different materials for microfluidics applications. Further detail of materials properties is provided in Tables 1-3 in Appendix 1.

**Material Selection Decision Support Chart ‘A’**

![Material Selection Decision Support Chart 'A'](image-url)
Material Selection Decision Support Chart ‘B’

Desired Device Throughput (nl per second)

Desired accuracy of reaction/result

1:10
1:100
1:1000
1:10000
1:100000
1:1000000
1:10000000
1:100000000
1:1000000000

Silicon
Flexible Web
Glass / Silica
Polycarbonate
Metal

Paper (wax)
PDMS
Manufacturing process selection:
In addition to material choice the aspiring product development engineer needs to consider manufacturing process.

The nature of these manufacturing processes influences the type and geometry of structures/tolerances which can be achieved, the use of device ‘real estate’ as well as the economics of manufacture.

The following process options are currently available on an industrial scale:

Micromachining (usually for metal)  
- Precision mechanical machining  
- Laser machining 
- Electro Discharge machining  

Key Characteristics  
- Low volumes possible; very low set up cost  
- Slow process, limited in feature sizes  
- Steepest draft angles/ any channel shape (except overhangs)

Planar processing (of silicon or glass)  
- Wet chemical etching  
- Dry etching (DRIE, Fused Silica only)  
- Powderblasting (Glass only)  
- Photostructuring

Key Characteristics  
- Very large volumes; medium set up cost; medium lateral feature sizes, small to medium channel depths  
- Slow process, medium setup cost, small feature sizes, high aspect ratio  
- Medium setup cost, large feature sizes, deep channels  
- Medium set up cost; medium feature sizes

Casting (of elastomers)  

Key Characteristics  
- High set up cost, low volume

Injection moulding  

Key Characteristics  
- High setup cost, medium batch sizes, medium aspect ratio

Hot embossing  

Key Characteristics  
- Medium set up cost, high batch sizes (especially if roll-to-roll).  
- High aspect ratio possible, shallow depth of channels.

See also next two pictures and Table 4 in Appendix 2.
Process Selection Decision Support Chart ‘C’

```
Harshness of environment (T, P, Chemical Reactivity)
<table>
<thead>
<tr>
<th>Easy</th>
<th>1</th>
<th>10</th>
<th>100</th>
<th>1000</th>
<th>10000</th>
<th>100000</th>
<th>10E6</th>
<th>10E7</th>
<th>10E8+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

Number of devices to be produced per year

- Laser
- Etching
- Casting
- Moulding
- Roll to Roll Hot Embossed
- Xerography / Wax
- Planar Processing
Process Selection Decision Support Chart ‘D’

- Roll to Roll Hot Embossed
- Moulded
- Laser
- Powderblasting
- Planar Processing
- Xerography
- Casting

Desired accuracy of reaction/result:

1:100
1:1000
1:10000
1:100000
1:1000000
1:10000000
1:100000000
1:1000000000
1:10000000000
1:100000000000
1:1000000000000
1:10000000000000

Desired Device Throughput \( \text{nl per second} \)
Device Design Guidelines

So now you have a feeling for what material your device might be made of and what manufacturing process it might be made by when it finally gets to market! These decisions have an impact on the physical format of the device itself because of issues like: feedstock, cost of materials and the limits and capabilities of the manufacturing process. The following sections will explain in more detail for the most common materials and processes.

Microfluidic chips typically are composed of a set of different basic structures in order to realize the required functionality and the basic microfluidic operations (e.g. mixing, separation, transport, splitting, etc.), respectively. In the following, some basic microfluidic structures are listed:

Channels

Chambers / Wells / Cavities

Pillars

T- or Y-Junctions

Holes

The design guidelines below address issues such as: profile of channels, aspect ratio (height: width) of features, spacing of features (to each other and to edge of device), as well as provision for connectors.
We are grateful to Dolomite Microfluidics, IMT Masken und Teilungen and Micronit Microfluidics for providing the information below. A more extensive version of their design guidelines can be found at: www.microfluidicsinfo.com/glassmanufacturedolomite.pdf or by contacting directly the suppliers on: www.dolomite-microfluidics.com, www.imtag.ch or on: www.micronit.com

Wafer and chip sizes
100*100 mm: containing for example 12 chips with dimension of 45*15 mm each
150*150 mm: containing for example 100 chips with dimension of 15*15 mm each

Glass layer thicknesses
Standard thicknesses 0.7, 1.1 and 2 mm; minimum thickness 30 μm; thicker is also possible

Structures made by wet isotropic etching:
Resulting surface roughness: < 5 nm
Channel width: mask width + 2 * channel depth; minimum mask width 5 μm, 1 μm on special request
Etch depth range 0.010-500 μm

Structures made by powder blasting
Feature size accuracy is about 25μm
Channel depth: 100 μm and more
Thru hole dimension: typically 0.2mm and up
Shaped wells can be round or rectangular. The sides of the wells will not be completely vertical, but sloped at an angle of 70°; on request the angle can be varied between 65° and 80°.

The average roughness of the channels will be between 0.8 and 2.5 μm

Structures made by dry etching (for fused silica only)
Channel width: 0.1 to 3 μm
Chip edge to channel 750 μm (low pressure) 2 mm (high pressure)
Minimum spacing between structures: 5 μm +2.6 * etch depth
Minimum Through Glass Via (TGV) diameter: 100 μm, needed overlap area 200 μm
Minimum inside radius: minimum spacing / 2

Drilling holes:
Typical diameters between 0.2 to 10 mm

Multiple layer chips / bonding of glass cover:
Standard alignment accuracy between two bonded layer: +/- 5 μm, on special request +/- 2 μm
Thermally bonded cover can withstand pressures up to 300 bar (also depending on geometry)

Cold bonded over can withstand pressures up to 50 bar
Thinnest possible total thickness of multiple layer chips 100 μm

Dicing and breaking
Dicing standard dimension is 3mm and up, dimensional tolerance +/- 100μm
Scribing standard dimension is 5mm and up, dimensional tolerance +/- 150μm and no cooling fluids are needed which is beneficial if SideConnectors are used.
Breaking standard dimension is 10 mm and up, dimensional tolerance +/- 300μm and no cooling fluids are needed which is beneficial if SideConnectors are used.

Edge connection (4 connection ports)

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1 45* 15 mm is de facto standard chipsizes, other standard lengths are 15, 22, 30 or 90 mm, but the customer is free to choose his or hers own sizes, as long as it fits on a wafer.
One of the small sides of the chip contains the four connecting holes; an area of 5.5 * 15 mm is needed; the drilled fluid holes need to be spaced 2 mm from the small edge of the chip & evenly spaced 3 mm from each other.

Side connection (individual connection ports)
For single edge connectors a pitch of ≥ 2.5mm can be used

Top connector (6 or 9 connecting ports)
When more connections are needed, 30 or 45 mm wide chips can be used; an area of 5.5 * 30 resp. 45 mm is needed; the drilled fluid holes need to be spaced 2 mm from the small edge of the chip and in sets of three evenly spaced 3 mm from each other, with 6 mm between the groups.

Top connector with 2 x 5 connecting ports or more
Connection holes are spaced 5 mm center-to-center, with a center-to-chip edge distance of 2.5 mm. A standard pattern of 2 x 5 holes on either side of a chip are oriented in a U-pattern. However, with the mentioned spacing, ports all across the chip surface can be provided. Hole diameter is typically 1.6 mm with a conical shape narrowing towards the chip interior.

Circular connector (8 connection ports). The eight fluidic ports are positioned on 4.5mm radius with 45° angular spacing. Hole diameter is typically 380 μm.
Condensed version of the design guidelines for integrated electrodes

We are grateful to IMT Masken und Teilungen and Micronit Microfluidics for providing the information below. A more extensive version of their design guidelines can be found at: www.microfluidicsinfo.com/electrodesimt.pdf or by contacting directly the suppliers on: www.imtag.ch

Preferred materials for integrated electrodes: Pt or Au
Metal layer thickness: between 50nm and 200 nm using standard sputtering or PVD, 1 μm or more by galvanic processing
Minimal feature size: 2 μm (depending on the layer thickness)
Access to electrodes: through chip holes or side connectors
Bonding of chips with electrodes within the fluidic system
  - Deform glass at elevated temperatures
  - Electrode recess
  - With intermediate layers: using intermediate polymer layers generating a hybrid chip, electrodes inside a channel on both top and bottom of the channel can be provided, thereby eg. providing a uniform electric field between both electrodes.
Condensed version of the design guidelines for polymer/injection moulding

We are grateful to Sony DADC for providing the information below. A more extensive version of their design guidelines can be found at: [www.microfluidicsinfo.com/polymermanufacturesony.pdf](http://www.microfluidicsinfo.com/polymermanufacturesony.pdf) or by contacting them on: [www.sonydadc.com](http://www.sonydadc.com)

Chip sizes
- Maximum lateral dimension of the moulded component (length x width) = MTP format, preferably credit card or Microscope slide 25mm x 75mm, with maximum overall thickness of 5mm (preferably <1.5mm)
- Minimum thickness of the base plate = 0.8mm (remaining thickness “below” structures 0.5mm) – if the moulded component is only ca. 25mm x 75mm the minimum thickness can be 0.6mm

Distance of structures to component edges = min. 2mm

Typical tolerances: According to DIN ISO 2768-1 f-fein

Design rules for structures created by high speed milling:
- Minimum dimension in the plane = 50µm
- Aspect ratio for structures sticking out of the base areas (smallest dimension in the plane / height of the structure) ≤ 1:1 (if the feature size is smaller than 100µm the aspect ratio should not be ≤ 1:0.5)
- Aspect ratio for structures going into the base area (smallest dimension in the plane / depth of the structure) ≤ 1:2 (if the feature size is smaller than 10 µm the aspect ratio should not be ≤ 1:1.5)
- Maximum height of a structure = 5mm
- Minimum radius at inside corners in the plane = 5µm
- Minimum radius at outside corners in the plane = 30µm
- Minimum distance between two structures = same as structure height but minimum 50µm

Stepped structures or ramp structures are possible
- Minimum draft angle 3°, preferably 5°
- Undercuts are not possible

Design rules for inserts created by lithography:
- All structures at one side of the moulded component either sticking out of the base or going into the base
- Minimum dimension in the plane = 1µm
- Aspect ratio for structures sticking out of the base areas (smallest dimension in the plane / height of the structure) ≤ 1: 0.5)
- Aspect ratio for structures going into the base area (smallest dimension in the plane / depth of the structure) ≤ 1:1.5)
- Maximum height or depth of a structure = 70µm
- Minimum radius at inside corners in the plane = 1µm
- Minimum radius at outside corners in the plane = 5µm
- Minimum distance between two structures = at least same as the either the height or width of the structures (whatever is larger)
- Stepped structures or ramp structures are possible
- Usual draft angle 10° (if there is only one structure height/depth) up to 15° (if there are more than one structure height or ramp structures)
- Undercuts are not possible
Condensed version of the design guidelines for Imprint Techniques

We are grateful to EV Group for providing the information below. A more extensive version of their design guidelines can be found at: www.microfluidicsinfo.com/EVGguidelines.pdf or by contacting them on: www.EVGroup.com

General design rules in UV Nanoimprint:

UV Nanoimprint is designed as massive parallel replication process of sacrificial layers or permanent layers. Etch selectivity is comparable to standard semiconductor processes but needs to be adjusted for the underlying bulk material. Using glass in suspension, glass micro and nanostructures without costly vacuum processes such as metallization and etching can be manufactured. Furthermore UV nanoimprint lithography enables the manufacturing of 3D structures which might reduce the required steps for device manufacturing. In any case the most important aspect in imprint lithography is the master or stamp manufacturing technique. One has to be aware that certain features like nanoscale 3D structures require unconventional manufacturing techniques.

- Maximum substrate size (length x width) = 300 mm x 300 mm
- Manufacturing throughput: > 60 units per hour
- Maximum substrate thickness = 10mm (Semi Standard)
- Minimum substrate thickness = 0.05 mm on foils; 150 µm on semiconductor materials
- Top to bottom alignment: possible
- Minimum structure size: down to 35 nm for high volume manufacturing
- Maximum structure size: geometry dependent but up to 5 mm in diameter demonstrated
- Maximum aspect ratio: 1:4, for sub µm structures ideally the aspect ratio stays below 1:2

General design rules in Hot Embossing:

Hot embossing is also considered as massive parallel replication process mostly for reshaping bulk thermoplastic materials. Dependent on equipment force and temperature, materials of glass transition temperatures up to 650° on up to 300 mm round substrates can be processed. This would even allow to thermally emboss into certain glasses directly such as Borofloat glass.

- Maximum substrate size (length x width) = 300 mm round
- Manufacturing throughput: equipment dependent
- Maximum substrate thickness = 15 mm (Semi Standard)
- Minimum substrate thickness = 0.100 mm on foils
- Top to bottom alignment: possible
- Minimum structure size: down to 35 nm for high volume manufacturing
- Maximum structure size: geometry dependent but up to several 100 µm
- Maximum aspect ratio: 1:15 (w:h), for sub µm structures ideally the aspect ratio stays below 1.2

General design rules in Roll-to-Roll Hot Embossing:
Using rolls instead of plates, roll-to-roll enable continuous molding with significant advantages in operational speed and device throughput. In roll-to-roll hot embossing, a thermoplastic sheet passes between two rotating rollers. The deformation of the thermoplastic material under the pressure and elevated temperature of the mold imprints the structures into the polymer. Roll-to-Roll hot embossing is especially well suited for structuring of micron and especially sub mm structures. Furthermore the technology implies advantages over mainstream reshaping technologies such as injection moulding if structured thin films are required.

- Maximum substrate size (length x width) = 300 mm web width, Continuous mode operation
- Manufacturing throughput: up to 10 m/min structure dependent
- Maximum substrate thickness = 0.5 mm
- Minimum substrate thickness = 0.100 mm
- Minimum structure size: down to 50 nm for high volume manufacturing
- Maximum structure size: geometry dependent but up to several 10 µm
- Maximum aspect ratio: 1:2 (w:h)
Preferred chipsizes and interconnections

We are grateful to Dolomite Microfluidics, PhoeniX and Micronit Microfluidics for providing the information below. More information can be found at: www.dolomite-microfluidics.com or on: www.micronit.com

Although many different chipsizes are used and can be used for microfluidics, for several reasons it might be advisable to adhere to certain chipsizes that are commonly used and supported by the supply chain.

The analytical industry is using microtiterplates with standardized dimensions. (See: ANSI/SBS 4-2004). Based on this specification microfluidic chips are offered which have the same outer dimensions. The microfluidic connections are mostly miniluers, placed on the borders of the chip with a pitch of 4.5 mm according to the positions of the outer wells of the standard layout. See next figure:

Another standard chipsize often used is the microscope slide format. There is some variation in dimensions of those slides, but it seems that the industry is slowly heading towards 75 * 25 mm size, although slightly larger slides (3 * 1 inch) are still being sold. There are two options to connect tubes to these slides: In the case of micromolded chips, miniluer interconnects at one or both sides of the chip are the standard (see next figure).
The pitch between the contacts are the same as with microtiterplate: 4.5 mm. There is however an alternative. When the microfluidic device is created by wetetching / powderblasting of a glass plate or by structuring of polymere layers on top of the plate, a clamped contact at one or both of the smaller sides is the most appropriate. (see next figure). An important advantage of clamped contacts compared to miniulators based connections is the lower dead volume of the microfluidic path and the ability to make several interconnections at the same time. For instance by using Chipholders.

Glass chip to be used in chipholders

(In between those sizes the “credit card” size is proposed: 83.3 mm x 52.0 mm x 2.64 mm.)

In many cases it makes sense to use smaller chipsizes. In that case a set of sizes is proposed: 15*15; 15*30 and 30*30; 15*45. The preferred interconnection layout for such chips is given in the next figures:
Next figures give an overview of all preferred chipsizes and their preferred interconnection methods:
Design guide for chip layout & connections

Material
- Polymer
- Glass

Chipsize
- Microtiter plate: 127.76 * 85.48 mm
- Microscope slide: 75*25 mm
- Microscope slide: 75*25 mm
- 45*45; 45*15; 30*30; 30*15; 15*15 mm

Connection
- Miniluer
- Miniluer
- Clamped
- Clamped
The Future

Technologies for realising microfluidic devices are changing fast. In the foreseeable future: Roll-to-roll manufacture, paper based microfluidic, 3D printing etc. might progress from being research tools, to mainstream production. Also the economics of production may well change if it becomes possible for new devices to benefit from economies of scale of other devices, possibly even in other industries.

Standards

This is a controversial subject as considerable commercial interests are at stake! At present there are a large variety of products and solutions available.

On the one hand it can be argued that upfront investment in achieving the highest possible level of integrated design for purpose will provide the lowest possible cost per unit (and for very high volume production this will be the case). On the other hand, reusing ‘platforms’ will enable the sharing of economies of scale across different products and possibly industries.

The MF5 consortium takes a pragmatic view. It is not possible to force any one solution on an unreceptive world – in particular if that would involve writing off costs already committed to particular solutions. However it is useful to encourage designs to use common formats things like: external format of devices, interconnects and certain features/functional sub-units. Contact MF5 for further information.

And Finally

This is a living document. We are interested in your feedback and involvement to improve it!

While we are grateful for help from members of the MF5 consortium, the reader should also check the supplier’s website for up to date information and contact potential suppliers with questions before committing to major development work.

We are also grateful to the members of the MF5 microfluidics consortium for their support and guidance in making this document and related initiatives possible. Please visit www.microfluidicsinfo.com and contact us on ceo@cfbi.com if you would like to join us and support initiatives like this.
Appendix 1 More detailed comparison of material properties

Table 1: Rough guide to properties of construction materials used in microfluidic processing

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>Glass</th>
<th>Polymer</th>
<th>Ceramic</th>
<th>Silicon</th>
<th>Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical properties</td>
<td>+++</td>
<td>+</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Chemical Inertness</td>
<td>++</td>
<td>+/-</td>
<td>+++</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>Surface properties</td>
<td>++</td>
<td>+/-</td>
<td>--</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>Thermal stability</td>
<td>++</td>
<td>+</td>
<td>+++</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>Biocompatibility</td>
<td>++</td>
<td>++</td>
<td>--</td>
<td>++</td>
<td>?</td>
</tr>
<tr>
<td>Hydrophility</td>
<td>+++</td>
<td>-</td>
<td>?</td>
<td>?</td>
<td>--</td>
</tr>
</tbody>
</table>

| User Advantages       | Shelf life | + | - | +++ | ++ | - |
|                       | Reproducibility | ++ | +/- | ? | +++ | - |

| Application Specific  | Porosity (absorption) | +++ | - | ? | +++ | - |

| Functionalization     | Integration of Electrodes | ++ | + | -- | +++ | -- |
|                       | Coating                  | +  | +/- | -- | +++ | - |
|                       | Built-in Electronics     | +  | -- | -- | +++ | -- |

| Manufacturing         | 3D structuring | -- | ++ | +++ | --- | -- |
|                       | Price           | -  | ++ | -- | -- | +++ |
|                       | Industrial infrastructure | + | ++ | + | +++ | --- |
|                       | Set up cost     | +  | -- | -- | -  | +++ |

There are of course many different kinds of polymers. The following two tables show the most important properties of the most commonly used ones.
Table 2: Short overview of properties of some materials

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Name</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>COC, Topas</td>
<td>Cyclo Olefin Copolymer (COC, Topas)</td>
<td>High transparency, temperature stability 140°C</td>
</tr>
<tr>
<td>PP</td>
<td>Polypropylene</td>
<td>Good mechanical properties, temperature stability 110°C</td>
</tr>
<tr>
<td>PC</td>
<td>Polycarbonate</td>
<td>High transparency, temperature stability 130°C</td>
</tr>
<tr>
<td>PTFE</td>
<td>Polytetrafluorethylene</td>
<td>High chemical and temperature resistivity, temperature stability 260°C</td>
</tr>
<tr>
<td>PEEK</td>
<td>Polyetheretherketone</td>
<td>High temperature resistivity, temperature stability 250°C</td>
</tr>
<tr>
<td>PS</td>
<td>Polystyrene</td>
<td>Transparency, temperature stability 80°C</td>
</tr>
<tr>
<td>PVDVF</td>
<td>Polyvinylidenefluoride</td>
<td>Chemical inert, piezo electric, temperature stability 150°C</td>
</tr>
<tr>
<td>SU8</td>
<td>SU8 sheets</td>
<td>Negative resist, quick mastering</td>
</tr>
</tbody>
</table>

Others: Borofloat glass, Teflon

Table 3: Chemical resistance of glass and the most commonly used polymers

<table>
<thead>
<tr>
<th></th>
<th>glass</th>
<th>PMMA</th>
<th>Polycarbonate (PC)</th>
<th>Polystyrene (PS)</th>
<th>COP</th>
<th>COC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrated acids</td>
<td>yes</td>
<td>No</td>
<td>no</td>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Concentrated bases</td>
<td>no</td>
<td>No</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Diluted acids</td>
<td>yes</td>
<td>Yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Diluted bases</td>
<td>yes</td>
<td>No</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
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<tr>
<td>Alcohols</td>
<td>yes</td>
<td>No</td>
<td>yes</td>
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<td>Esters</td>
<td>yes</td>
<td>No</td>
<td>no</td>
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<tr>
<td>Ketones</td>
<td>yes</td>
<td>No</td>
<td>no</td>
<td></td>
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<tr>
<td>Aromatics</td>
<td>yes</td>
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<td>no</td>
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<tr>
<td>Halogenated hydrocarbons</td>
<td>yes</td>
<td>No</td>
<td>no</td>
<td>no</td>
<td>no</td>
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<tr>
<td>Aldehydes</td>
<td>yes</td>
<td>Yes</td>
<td>no</td>
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<tr>
<td>Oils, fats</td>
<td>yes</td>
<td>Yes</td>
<td>yes</td>
<td>mineral oils only</td>
<td>no</td>
<td>no</td>
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<tr>
<td>Amines</td>
<td>yes</td>
<td>Yes</td>
<td>no</td>
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Table 4: Other properties of glass and polymers compared

<table>
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<tr>
<th></th>
<th>Glass</th>
<th>PMMA</th>
<th>Polycarbonate (PC)</th>
<th>Polystyrene (PS)</th>
<th>COP</th>
<th>COC</th>
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<tbody>
<tr>
<td>Optical</td>
<td>++</td>
<td></td>
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<tr>
<td>Ease of chemical</td>
<td>+++</td>
<td>Y</td>
<td></td>
<td></td>
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<tr>
<td>modification of surface</td>
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<tr>
<td>properties</td>
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<tr>
<td>Hydrophobicity</td>
<td></td>
<td></td>
<td>Less than others</td>
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<tr>
<td>Permeability</td>
<td>nil</td>
<td></td>
<td>high</td>
<td>low</td>
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<tr>
<td>Melting point</td>
<td>Very high</td>
<td></td>
<td>low</td>
<td>T_g 70° C</td>
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### Appendix 2 More Detailed Comparison of Manufacturing Processes

#### Table 5: Indicative design rules of the different industrial processes compared

<table>
<thead>
<tr>
<th></th>
<th>glass/planar processing</th>
<th>polymer/injection moulding</th>
<th>Polymer/embossing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical chip sizes (mm)</strong></td>
<td>15x15; 15 x 22.5; 15x30; 15x45</td>
<td>Credit card or Microscope slide: 25x75</td>
<td>Credit card or Microscope slide: 25x75</td>
</tr>
<tr>
<td><strong>Chip thickness (mm)</strong></td>
<td>thinnest 0.03</td>
<td>standard 0.7, 1.1, 2.0</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>standard 0.7, 1.1, 2.0</td>
<td>thickest 5 (preferably &lt;1.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Channel width (μm)</strong></td>
<td>mask width + 2 x channel depth; minimum mask width 10 μm, 1 μm on special request</td>
<td>&gt;50</td>
<td></td>
</tr>
<tr>
<td><strong>Etch depth (μm)</strong></td>
<td>0.010-500</td>
<td>&lt;70</td>
<td></td>
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<tr>
<td><strong>Minimum spacing between structures (μm)</strong></td>
<td>5 +2.6 * etch depth</td>
<td>Same as structure height, but at least 50</td>
<td></td>
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<tr>
<td><strong>Aspect ratio channels</strong></td>
<td>&lt;1:2</td>
<td>&lt;1:2</td>
<td></td>
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<tr>
<td><strong>Electrodes (μm)</strong></td>
<td>Minimal feature size 2</td>
<td>Standard feature size 5</td>
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</tr>
<tr>
<td></td>
<td>thickness 0.05-1</td>
<td></td>
<td></td>
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</tbody>
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