Low-cost Injection Moulding Strategies for the Fabrication of Organ on a Chip Devices

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Introduction

Polydimethylsiloxane (**PDMS**) based devices are commonly used for Organ on a Chip applications, however they possess serious material **property limitations** [1,2]. In addition, the **soft-lithography** approach [3,4] used to fabricate such devices limits their potential **translational impact**.

Injection moulding, which is compatible with a wide range of polymers, addresses these issues. However, the **high cost** associated with micro-fabricated moulds is currently hindering the use of injection moulding as a manufacturing option for microfluidics research applications [5].

Here we describe a method, combining **3D printing, micro-milling** and **soft-lithography**, to develop a flexible approach suitable for **low-cost prototyping** of Organ on a Chip devices (Fig 2).

Methodology

The injection moulder was fitted with a **steel bolster tool** machined with a cavity to accommodate a **3D printed tool insert**. A 3D printed tool insert was manufactured to include the (injection) moulding cavity and, depending on the device feature size, a space to accommodate the **patterned inlay**. Micro-patterned inlays fit into the 3D printed insert, so that the patterned surface can be injection moulded over.

At low cost and with a fast turnaround, **different** patterned **inlays** can be fitted into the 3D printed **inserts** and different 3D inserts can be manufactured to mould different sized parts using both standard and micro injection moulding (Fig 1).

Pattern **replication** and **lifetime** of the inserts/inlays were studied in relation to process parameters.

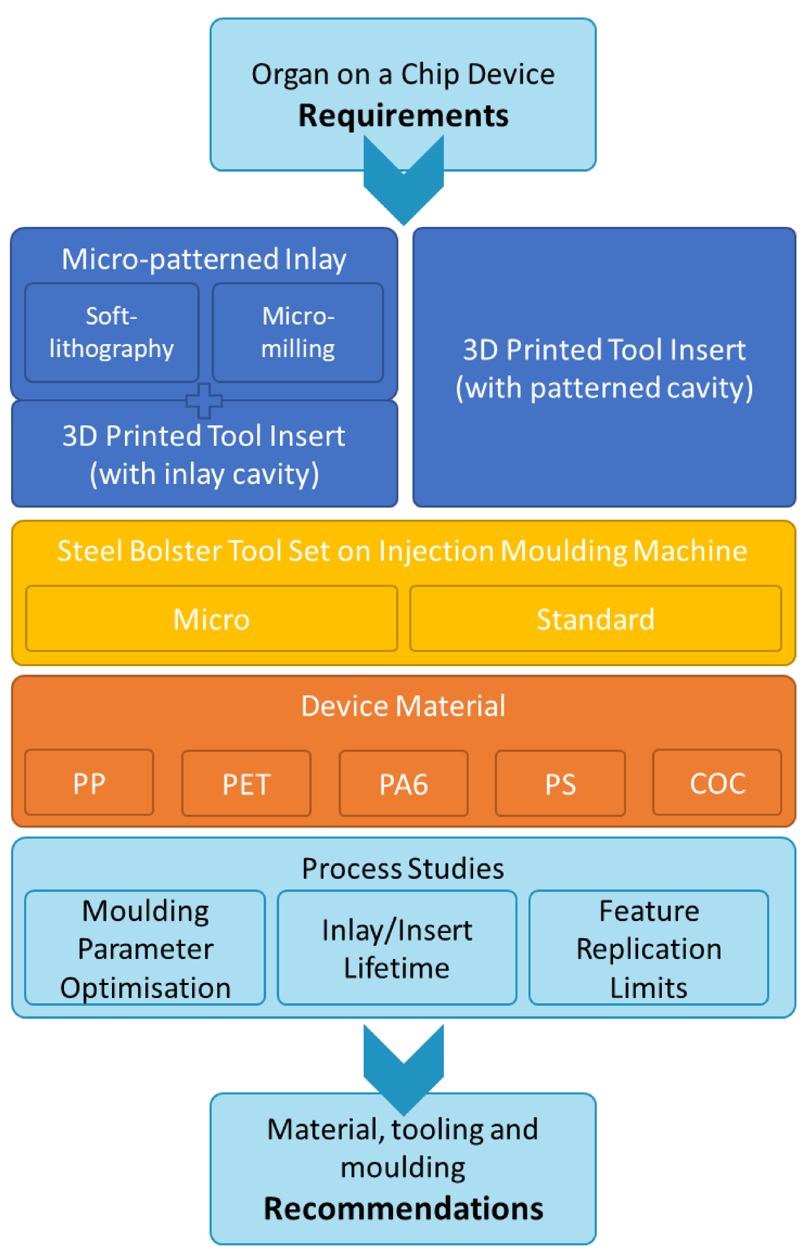


Figure 1: Methodology diagram. Full investigation of these experimental options would facilitate low-cost tooling recommendations to be made based on Organ on a Chip device requirements.

CONCEPT

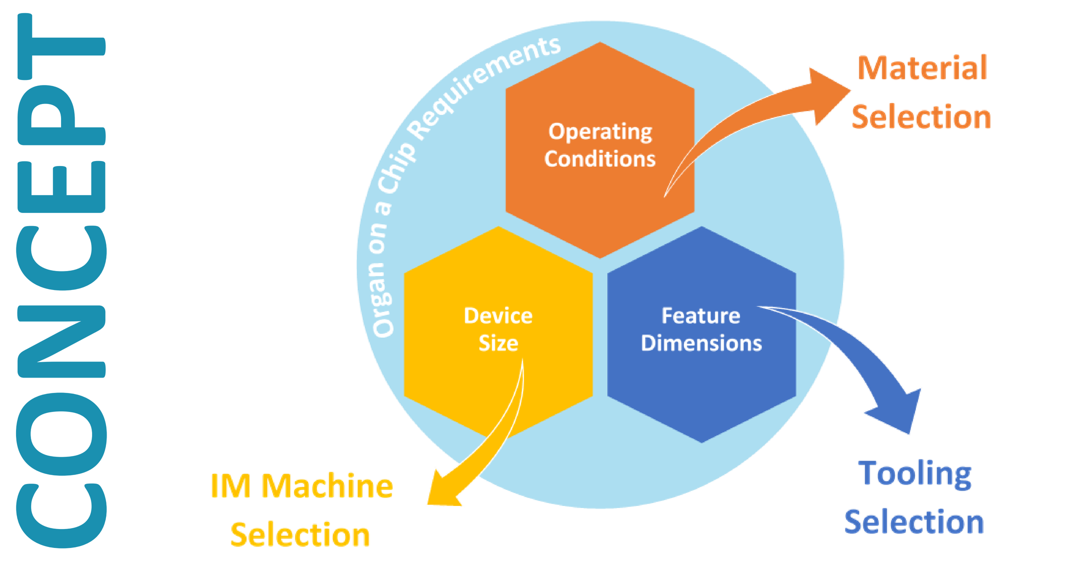


Figure 2: Concept diagram. Three key features of a required Organ on a Chip device determine an appropriate flexible, low-cost injection moulding prototyping strategy.

Materials

Three **desirable material properties** were selected, based on candidate device applications. These were:

- Optical **transparency** (High & Low)
- **Solvent Resistance** (High)
- **Oxygen Permeability** (High & Low)

Fig 3 shows the plastic materials suitable for **each property combination**. Materials in **green** have the added benefit of **chemically compatibility**.

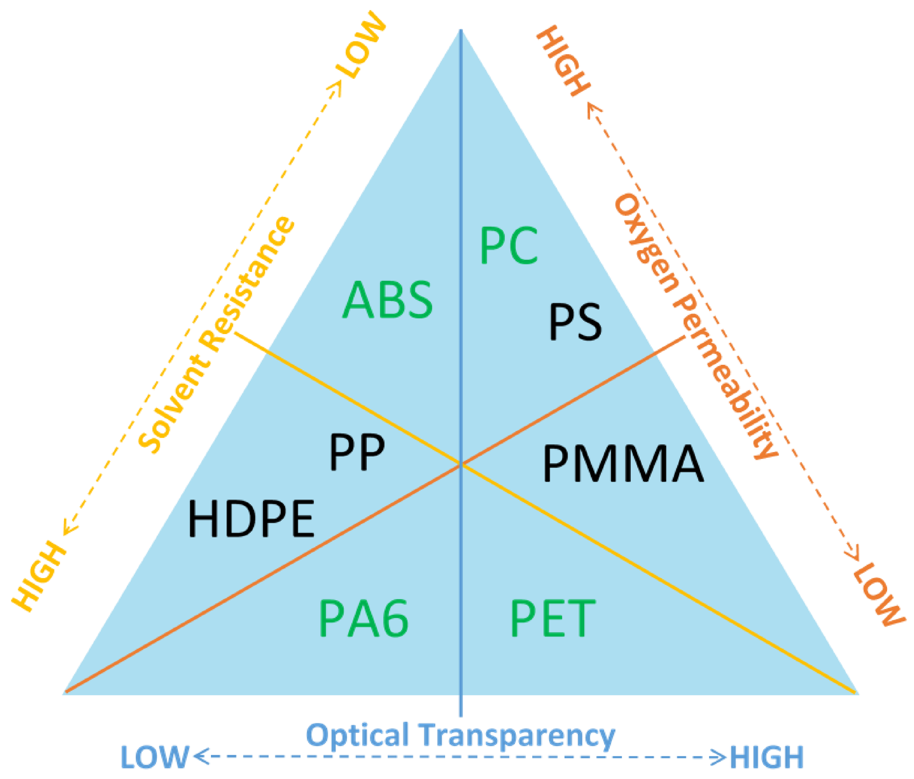


Figure 3: A range of injection moulding thermoplastics covering combinations of the three selected desirable material properties.

A shortlist of polymers were investigated for their low gas permeability (**PET**), transparency (**PS, COC**), opacity (**PA6**) and solvent resistance (**PP**).

Fabrication

In trials so far, **PDMS inlays** (feature size: 25 µm – 100 µm) were manufactured using a **standard soft lithography** process and fitted into 3D printed inserts. In addition, devices (feature size: 0.5 mm – 1.0 mm) were successfully injection moulded using **3D printed insert tooling**.

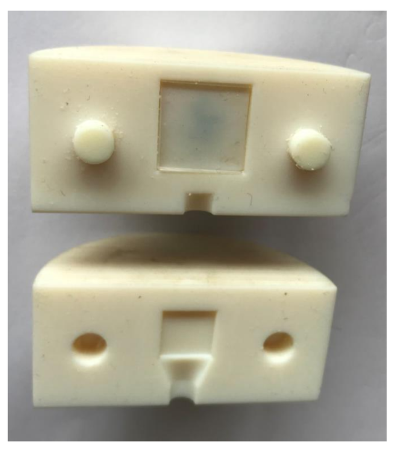


Figure 4: 3D Printed tool insert with injection mould and inlay cavities.

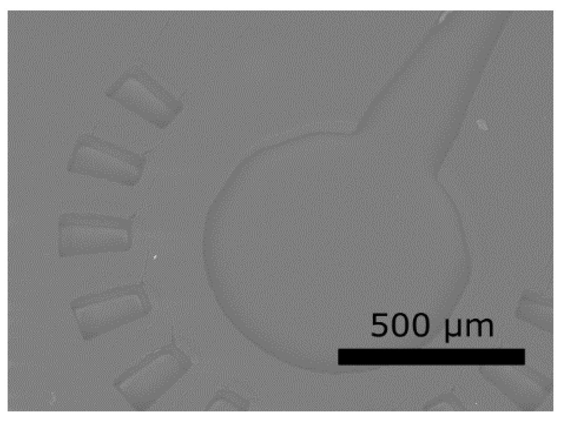
3D printed inserts (Fig 4) were designed with a fan gates and side injection points and fabricated using a proprietary **UV curing acrylic** on a Stratasys J750 Polyjet printer.

Battenfeld 50 Microsystem (Fig 5) was used to injection mould devices in **polypropylene (PP)**.

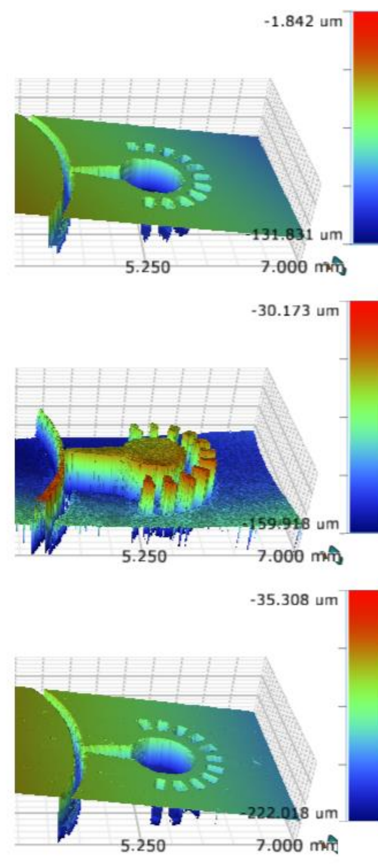
Figure 5: Micro injection moulder.

Results

To **evaluate** the pattern **replication** achieved using this process, SEM images and **surface profiles** of injection moulded **parts and PDMS inlays** were measured using a Bruker Contour GT **Interferometer**, and then compared (Figs 6 to 9).

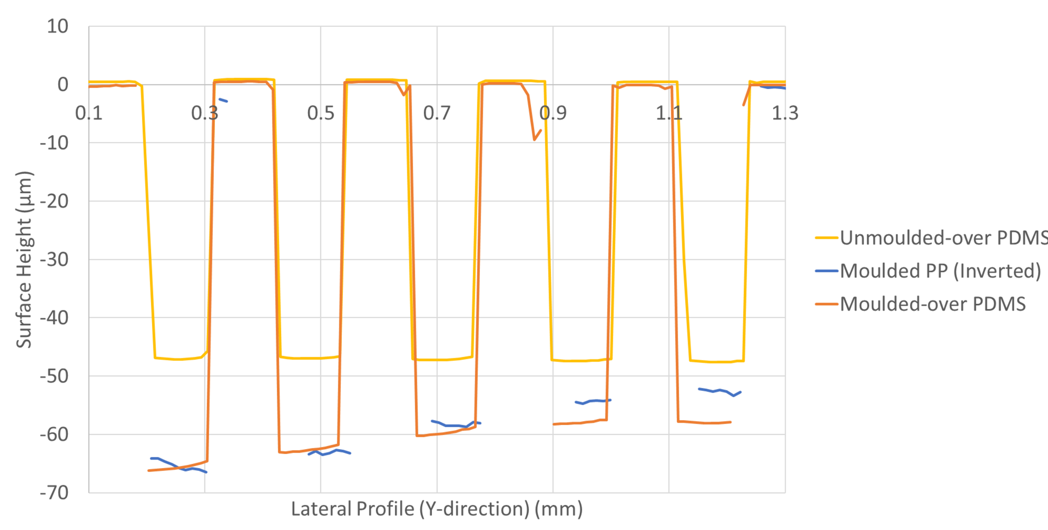


Above, Figure 6: SEM micrograph of injection-moulded devices (PP) based on PDMS inlay.



Right, Figure 7: 3D surface profiles of PDMS inlays before moulding over (TOP), after moulding over (BOTTOM), and the corresponding PP injection moulded device (CENTRE).

Below, Figure 8: Surface profile cross section of the radial feature shown in Figs 6 & 7.



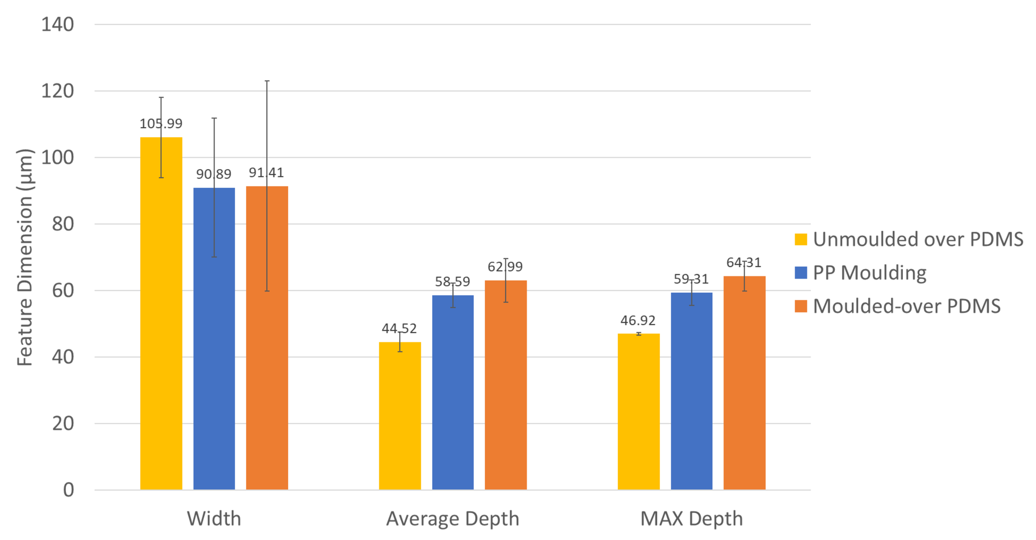


Figure 9: Mean profile dimensions of the radial feature shown in Figs 6 & 7.

Conclusions

Using **standard process parameters**, features with **100 µm** width and **50 µm** depth were **successfully** replicated by **injection moulding** over PDMS micro patterned inlays in 3D printed inserts. **Further process optimisation** is required to achieve replication of features of **25 µm** or below.

3D printed insert tooling was also used to injection mould devices with **0.5 mm – 1.0 mm** feature sizes.

Next Steps

Next steps are to:

- **Optimise process parameters** for better feature resolution
- Determine maximum **lifetimes** for different tooling options
- Trial **smaller features sizes**, and
- Injection mould with **different materials**.

References

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We acknowledge funding from the Research Development Fund of the University of Warwick

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