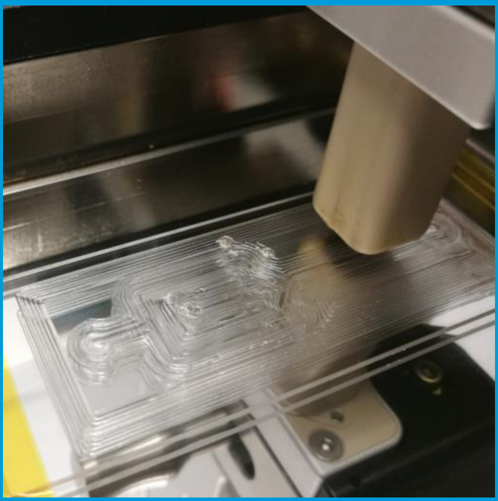
Fluidic Factory "Layer Offset" Function

Use of layer offset function to print on top of COC transparent substrate



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Aim & Objectives

This work demonstrates the experimental capability of the Dolomite Fluidic Factory 3D printer machine by showing an application for layer offset software function. This function is employed to print a perfectly bonded X-junction chip on top of a thin COC transparent sheet.

Introduction

Traditional fabrication techniques in the fluidic/microfluidic industry are too slow and expensive for a prototyping approach. So far, common 3D printing was not suitable for the microfluidic community, mainly because existing customer-grade printers focus on the external appearance and cannot deliver properly sealed channels embedded into a chip. Dolomite Microfluidics has developed the Dolomite Fluidic Factory, a highly innovative tool to enable FDM (fused deposition modelling) printing of microfluidic devices and overcome traditional challenges of 3D printing. Compared to other 3D printing techniques FDM is generally cost-effective and fast, and hence ideal for microfluidic rapid prototyping. Two key innovative features ensure fluidic sealing:

1. The software analyses the 3D geometry of the device and identifies the internal voids and surfaces. The print paths are then created from the inside of the device outwards and the print head deposits filaments in a continuous, leak-proof manner.
2. Fluidic Factory's clever design allows filaments to melt together when depositing on top of each other. A small volume of polymer (60 µL) is melted to a fluid state at very high temperatures and only held a few seconds before ejecting and depositing in a 'squashed' manner (Figure 1). This ensures excellent adherence, optimal polymer quality and leak-free channels.

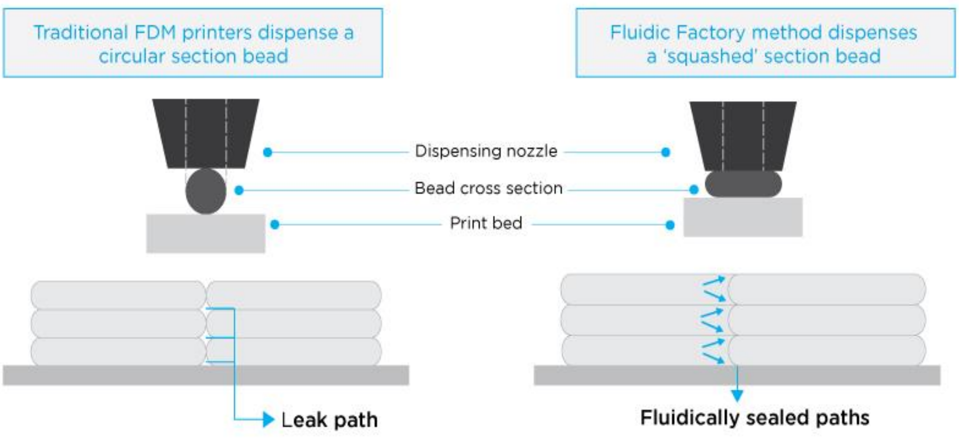


Figure 1. “Squashed” bead FDM printing method.

Cyclic olefin copolymer (COC) has been identified as the optimum polymer for the Fluidic Factory due to its unique properties: FDA approved, optically transparent, non-auto fluorescent, excellent chemical resistance, and biocompatible. It is a critical material for microfluidics in biology and medical environments.

Several fluidically sealed chips can be printed with the Fluidic Factory using the software standard settings. Moreover, an important software function further expands the range of applications of the Fluidic Factory 3D printer compared to other printers based on FDM methods. This function is the “Layer Offset” function, which allows the possibility to print on top of additional COC substrates. The function will be examined in the following section in a specific case study.

Layer Offset Function (Case Study)

In this section, we show how to use the Fluidic Factory “layer offset” function to print on top of a transparent COC polymer sheet. This function is particularly suitable in all the microfluidic applications such as particle tracking, crystallization studies, protein screening, liquid-liquid interface monitoring, etc, which require optical access within the microfluidic channels.

The COC substrate employed is a W = 75.5 mm x L = 25.5 mm x H = 1 mm grade 8007S-04 commercially available flat polished polymer sheet (Figure 2). The substrate has the same grade of the COC polymer used by the Fluidic Factory 3D printer. The two materials are compatible and perfectly bond to give a fluidically sealed structure.

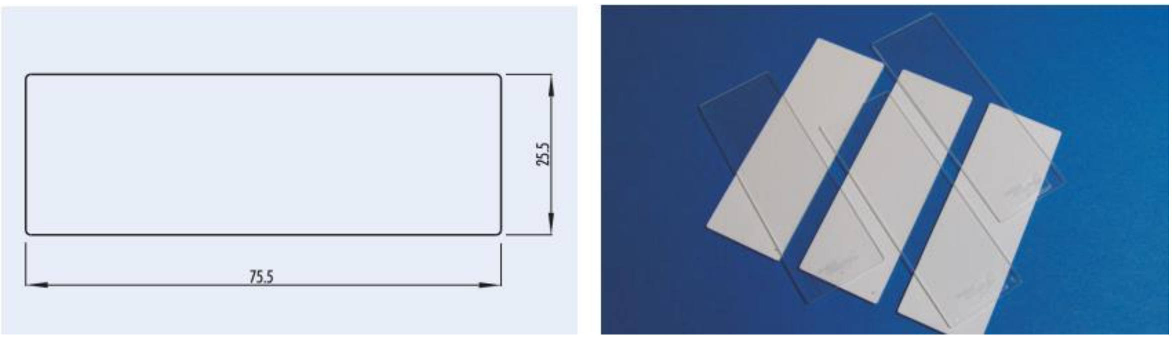


Figure 2. COC polymer substrate.

The chip which is printed on top of the COC substrate is a standard X-junction geometry for droplet generation with a 0.5 mm square section (Figure 3). The channels are designed on the upper part of the solid chip rectangular structure (W = 60 mm x L = 20 mm x H = 4) and are open on top. The channels will be fluidically sealed after bonding with the COC substrate.

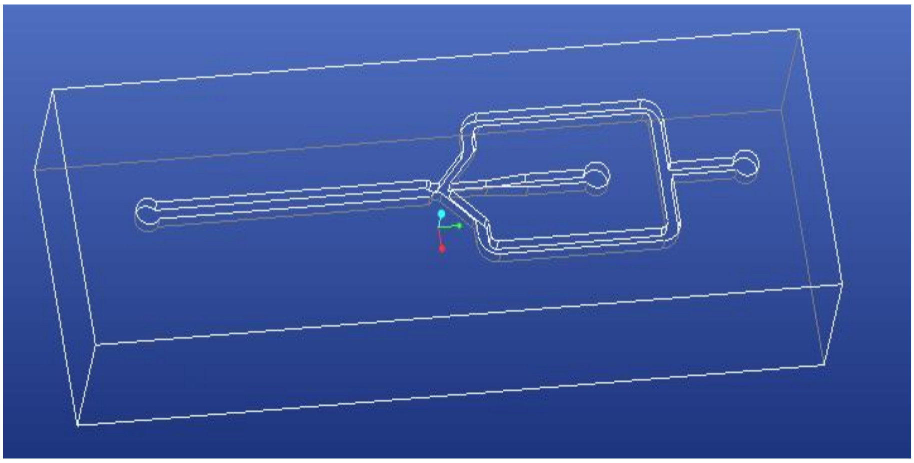
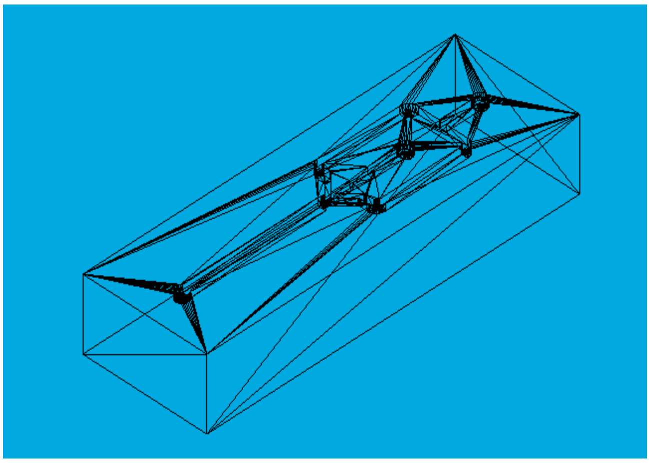


Figure 3. X-junction with top open channels CAD design.

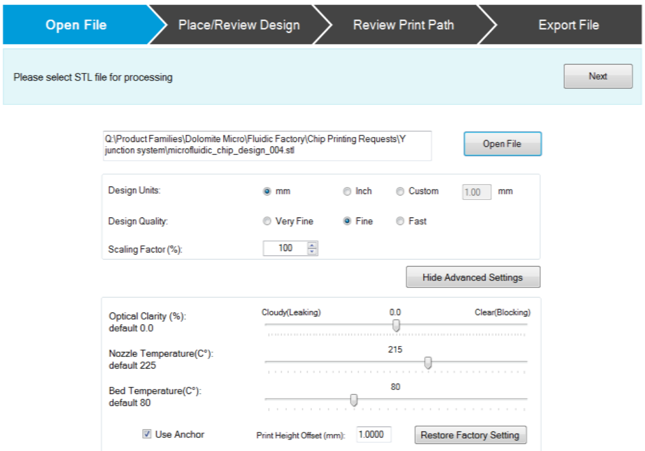
The microfluidic final structure is assembled by following the steps below:

(1) The CAD file is converted and saved as stl format.



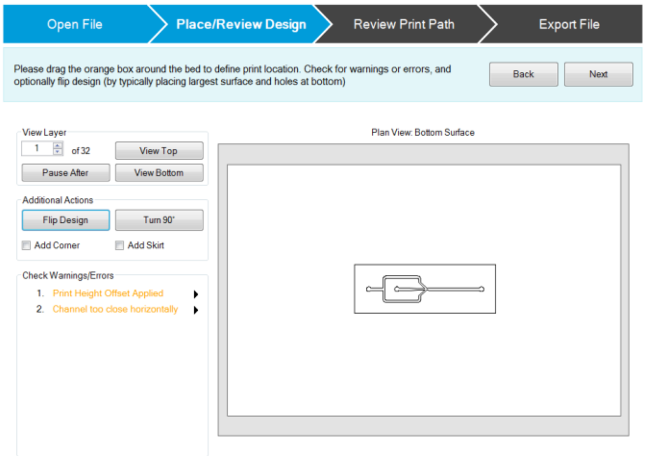
(2) The stl file is uploaded on the Fluidic Factory software. Fine quality mode and 100 % scaling factor are selected. On the “advanced setting” tab select “Print Height Offset” of 1 mm. This height corresponds to the COC substrate thickness. The other settings are left as default.

Press “Next”.



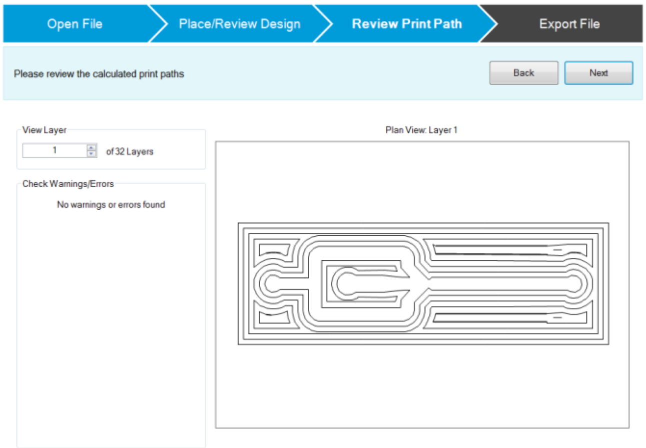
(3) The final chip is made of 32 layers of COC polymer beads arranged in a 3D structure (the different layers can be viewed using the top/down arrows). By default, the chip is printed with the X-junction channels facing the print bed in the middle of the print bed. This is the correct orientation for our case.

Press “Next”.



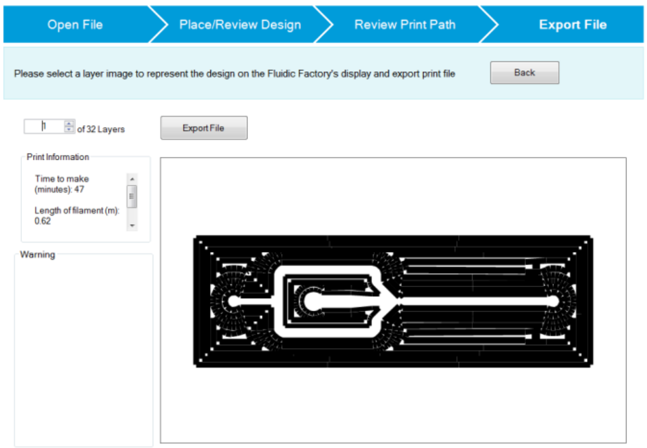
(4) The print path is reviewed.

Press “Next”.



(5) The print path is generated and the phff file is produced.

Press “Export File”.



The phff file is saved on a USB pen drive which is then plugged to the Fluidic Factory USB port. Before starting the printing process, the COC substrate is accurately placed in the middle of the print bed. A Kapton polyimide tape is applied on the substrate edges to stick the substrate on the print bed. This will maintain the substrate solidly attached to the print bed surface during the printing process (Figure 4a). Using the Fluidic Factory interface, the X-junction chip is printed 1 mm above the print bed (directly on the COC substrate) (Figure 4b).

Note, the temperature of the print bed is set as 80 °C (default settings). This temperature is slightly above the COC glass transition temperature (77 °C). This ensures a perfect chip-substrate chemical bonding without any geometry modification due to material softening.

a) COC Substrate on Print Bed

b) Substrate-Chip Bonding

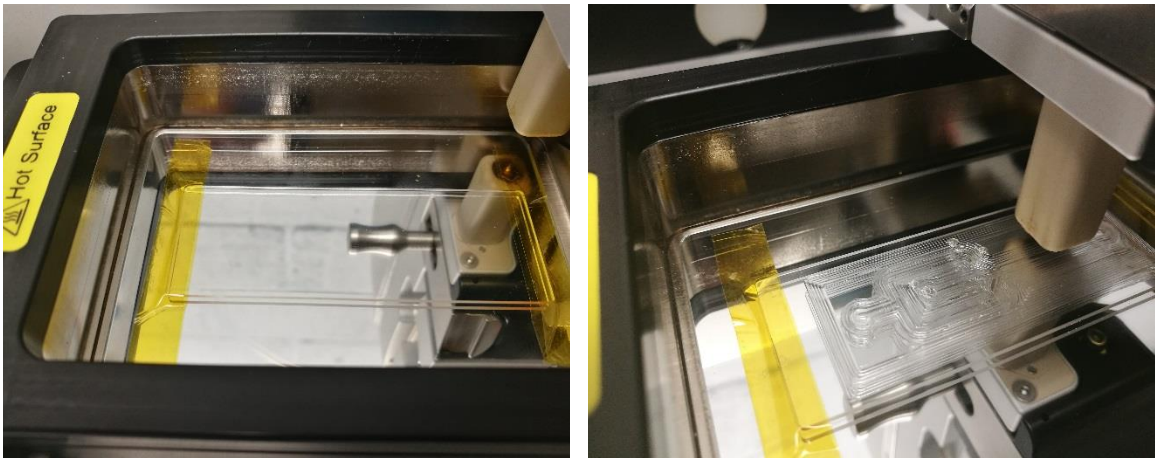


Figure 4. X-junction chip with layer offset printing.

The final structure is removed from the print bed and tested by flowing some red dye using a common pipette (Figure 5).

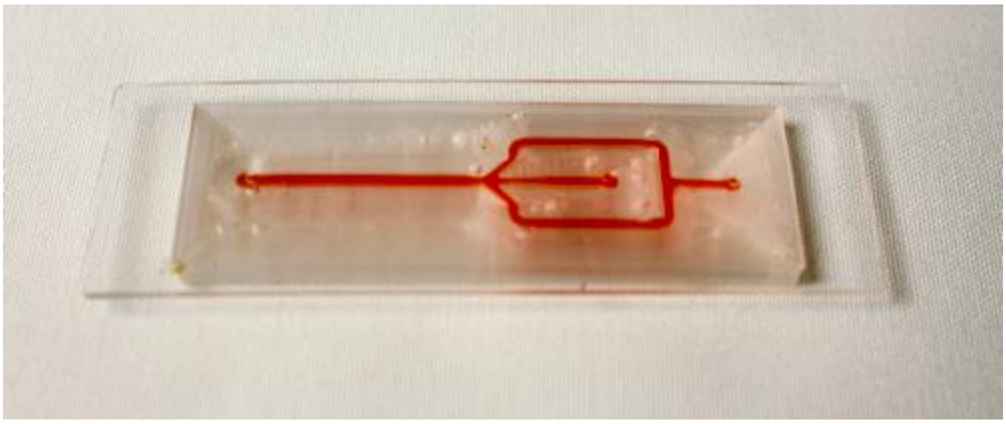


Figure 5. X-junction chip on transparent substrate.

To check if the entire structure is fluidically sealed a leaking test is performed by leaving the red dye within the channels for 24 h. The result shows that no leakage occurs between polymer layers and at the substrate-chip bonding interface. The two elements are solidly bonded and cannot be separated manually.

Other Examples

Layer offset is used to print ports on top of a COC manifold flat chip with parallel channels (Figure 6):

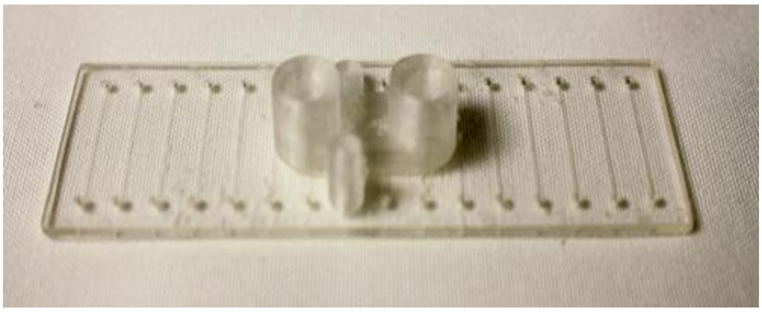


Figure 6. 3D printed channel ports on COC manifold flat chip.

A combination of layer offset and pause function is used to print a step-like Y-junction chip on top of a COC transparent substrate able to fit a Dolomite Top Interface 4-way (4mm) (Part No. 3000109) and Dolomite Linear Connector 4-way (Part No. 3000024) (Figure 7).

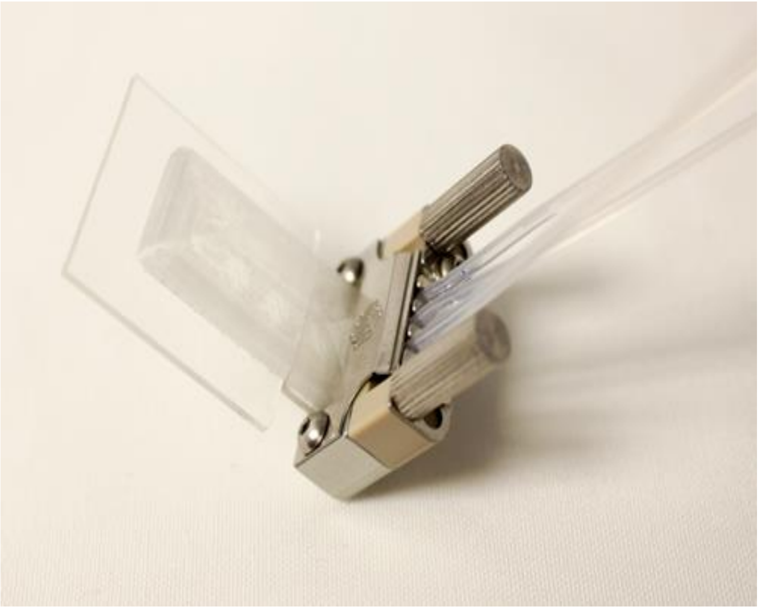


Figure 7. Y-junction on COC substrate fitting Dolomite connectors.

Conclusions

This application note showed the experimental capability of the Dolomite Fluidic Factory 3D printer by describing the use of the software layer offset function. The layer offset function allows the user to create 3D printed chip devices that are bonded on flat transparent polymer sheets. This is particularly useful when optical access is needed for screening applications. A perfect bonding between the two elements is possible if the COC polymer substrate and the COC extruded polymer have the same grade and therefore same chemical properties. As example, in this application we showed how to print an X-junction chip for droplet generation on top of a flat substrate. The final structure was perfectly bonded and fluidically sealed.

The layer offset function expands considerably the range of capability of the Fluidic Factory printer compared to the other printers based on fused deposition modelling techniques.