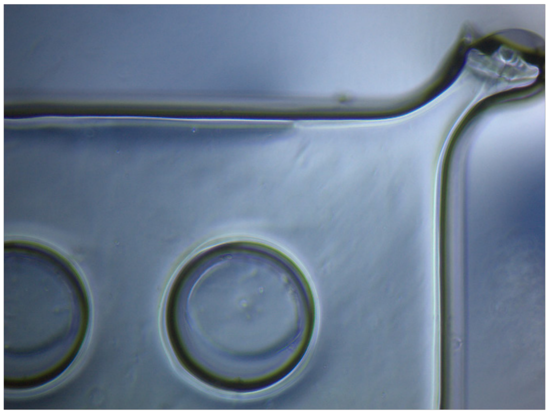
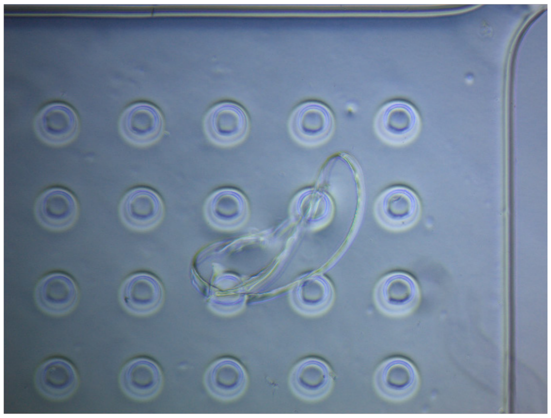
CUSTOMER STORIES

University of Pittsburgh Speeds Microwell Fabrication with Micro 3D Printing

Julio Aleman is a Bioengineering Ph.D. student at the University of Pittsburgh Swanson School of Engineering, where he is performing research in microphysiological systems. Like many researchers, he needed a microwell array system with individual wells that have a specific size, shape, and density. In fact, Aleman needed two different microwell arrays that would support the injection molding of hydrogels and serve as "master molds" – original molds that he could replicate. In turn, these replicate molds would be used for microwell fabrication.



Hydrogel mold of 64-microwell array



Hydrogel mold of 484-microwell array

To produce master molds like this, photolithography is often used. The process begins by spin coating a negative photoresist on a wafer to establish mold thickness and microwell depth. Photopatterning is achieved by light exposure through specialized high-resolution masks and finalized by chemical development of the master mold. Then, replicas of the master mold are made by casting pre-polymers over the negative template and polymerizing them by thermal curing. Polydimethylsiloxane (PDMS) silicone is the biocompatible polymer that is most often used. Typically, the production of master molds and masks requires specialized facilities and equipment. Micro-injection molding can also produce master molds, but the tooling is expensive and time-consuming to produce.

An Alternative to Clean Room Photolithography and Injection Molding

Projection Micro Stereolithography (PμSL) from Boston Micro Fabrication (BMF) allows for the rapid photo polymerization of a layer of resin with a flash of ultraviolet (UV) light at micro-scale resolution. PμSL offers an alternative to photosoft lithography, etching, deposition, micro-injection molding, and other traditional micro fabrication methods. Most of these traditional methods for mold and pattern creation limit a researcher's ability to create complex 3D channels. They're time-consuming and expensive, too.

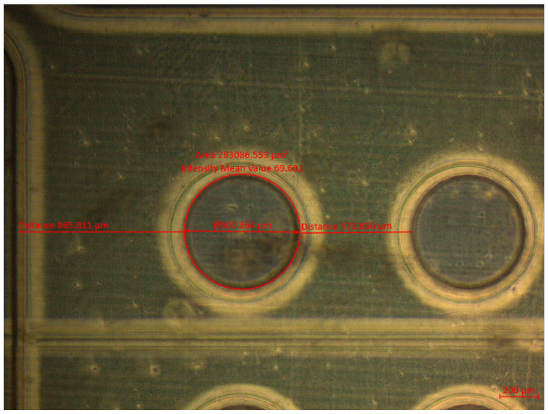
PμSL, a form of micro 3D printing, can produce small components with fine features and tight tolerances that are otherwise impossible to create. PμSL is capable of achieving a resolution of 2μm~50μm and a tolerance of +/- 5μm~25μm, thus providing ultra-high-resolution that is mold-free and mask-free for fast prototyping and end-use parts. There are other 3D printers that can produce micro-tooling, but as Aleman recognized, these systems are slow, expensive, and can't compete in terms of resolution, accuracy, and precision.

Project Requirements for Two Master Molds

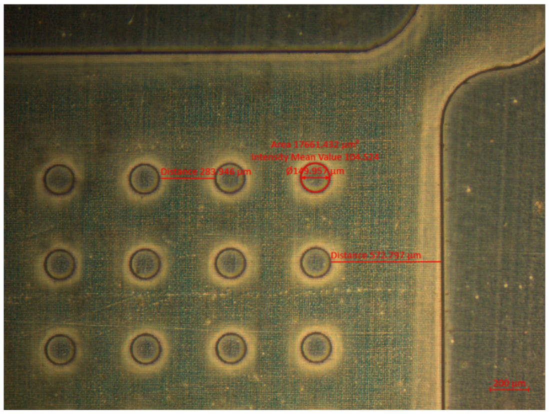
The University of Pittsburgh project needed master molds for replicate silicone molds that, in turn, would be used to make biomaterial-based microwells. Normally, master molds require a cleanroom and can be challenging to characterize. Researchers can't perform profilometer measurements until the molds are baked, and a mold with the wrong dimensions means lost time and money.

Aleman's project required fast turnaround times and high-volume production. Accuracy, resolution, and precision were critically important. Several PDMS replicas that were cured at 80° C were needed and the repeated processes on the master mold had to have little to no impact on the dimensions while the master mold was also securely fixed in a substrate. Aleman knew that he would need molds in two different sizes, and that the silicone molds should allow for the bottoms of the hydrogel micro-wells to have constant and defined amounts of biomaterial once injected and polymerized onto a glass slide. After some preliminary discussions, he ordered parts from BMF.

The master molds that the University of Pittsburgh asked BMF to produce were square with a defined hole-pattern. The first mold was for a 64-microwell array. It had an overall area of 20 mm x 20 mm and a thickness of 1.65 mm. The diameter for each hole and the distance between holes was 600 microns, or 0.6 mm, and the base of each of the microwells had a height of 50 microns from the surface. The second mold was for a 484-microwell array. The overall area was the same as for the first mold (20 mm x 20 mm), but the thickness for the second mold was significantly less at 1 mm. There were also more holes – and the holes were smaller. These wells measured just 150 microns, or 0.15 mm, in diameter with a similar base height of 50 microns.



3D printer mold for 64-microwell array



3D printed mold for 484-microwell array

Expert Advice and Flexible Material Selection

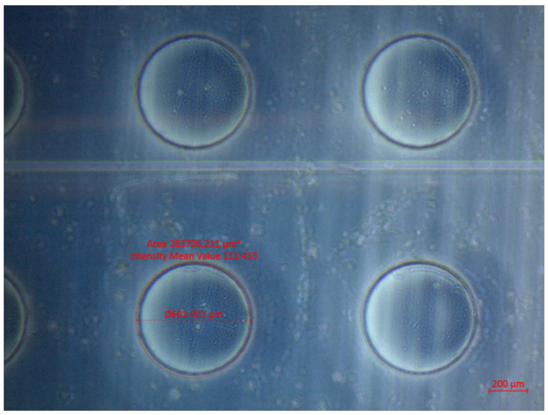
BMF's application team reviewed the designs for the University of Pittsburgh molds. They recommended increasing the thickness of the second mold to greater than 1 mm. Otherwise, a mold that is too thin may experience part distortion or internal stresses during the printing process. Aleman revised the thickness and BMF then created sample parts using GR resin, a high-performance engineering material that is black in color, able to withstand temperatures up to 102°C, and that supports sterilizing.

Because the COVID-19 pandemic limited Aleman's access to university facilities, the graduate researcher limited his mold evaluation to microscopy. In turn, this meant that parts made of a dark resin would be more difficult to inspect. To support microscopic techniques, Aleman needed a resin that would allow more light to pass through so that the features of the resin mold could be more clearly seen. The solution was to use an HLT resin instead. This yellow resin from BMF offers greater transparency but still provides good impact strength, heat resistance, and support for autoclave sterilization.

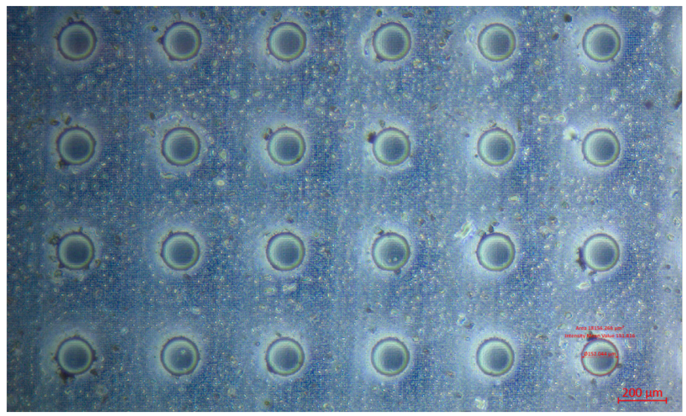
Speed, Accuracy and More Benefits of Micro 3D Printing

The University of Pittsburgh researcher liked how BMF delivered molds in just two weeks. Instead of waiting months to get a single injection-mold, he could provide a master mold to each member of the research team. The molds also exhibited dimensional stability and, unlike spin coating in photolithography, did not require multiple fabrication steps. After hard-baking some master molds in an oven overnight, Aleman attached them to a surface with double-sided electrical tape. The molds experienced only a 10 to 20 micrometer reduction in size, and that may have been caused by pressing the molds against the surface or the tape while the molds were still malleable from baking.

Aleman also reported that after approximately 10 cycles of PDMS molding, the BMF master molds did not exhibit any bending or deformation. To prevent sticking, the replicate molds were salinated with Vapor Phase Deposition (VPD). This treatment, which is also used with the SU8 molds in photolithography, permitted the easy detachment of the PDMS molds from the BMF master molds. Aleman reported that the master mold with the larger features was easily salinated over one hour of exposure while the mold with smaller features required five hours, or overnight exposure.



PDMS replica of 64-microwell array



PDMS replica of 484-microwell array

Proof-of-Concept for Your Next Project

As the University of Pittsburgh project demonstrates, researchers can use micro 3D printing to speed microwell array fabrication. If your application requires proof-of-concept parts such as master molds, BMF can harness the power of PµSL technology on your behalf. We can also help you with material selection and recommend the best microArch printer from our growing family of ultra-high resolution 3D printers.