We give shape to ideas.

Processing Guide

Mold Series for Injection Molding

Water-breakable cast materials for the creation of real functional prototypes or design studies with the target material

The One-Shot Mold (OSM) technology combines excellent compatibility of a 3D-printed mold with typical filling materials tolerating high temperature and pressure conditions as well as user-friendly removal resulting in automatable short cycle times.
Its water-breakable character enables a complete breakup when exposed to water with minimal swelling.

Materials can be used in

Tooling | Connectors | Household | Medical Applications

Performance Indicators

Print Accuracy	Very Good
Min Wall Thickness (Mold)	200 µm
Max Temperature at Process	380 °C
Max Pressure at Process	1200 bar
Minimum Thickness Filling Material	100 µm
Swelling in Water	Minimal

Preparation	
Construction	**Freedom of design**
Printing	**LCD, DLP, mSLA**
Washing	**5min IPA or Resin Cleaner 400**
Post-Curing	**Cure with UV**
Injection Molding	**High material compatibility**
Mold Removal	**Mold Remover 100 or Water**

Preparation

Safety Guideline

Mold 400 or 2200 VP is a chemical formulation in the liquid state and has to be treated as such until it is fully cured. Please use personal lab protection equipment such as appropriate gloves, goggles and lab coat. Wash contaminated body parts and equipment directly after occurrence and change contaminated gloves immediately. Do not consume the resin.

Danger

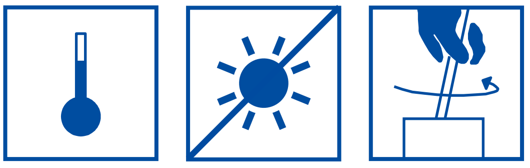
The information given in this document do not constitute a legally binding SDS, which will be provided at purchase.

Storage and Preparation

Please make sure the resin is stored at room temperature.

Please make sure the resin is not exposed to light.

Please stir resin prior to use.



Mold Construction

General Information

3D printing of a photopolymer mold vs shaping from a piece of metal brings several changes in the design and construction. Attention needs to be paid not only to the different thermomechanical properties between a polymer and a metal, but also to the fact that the mold is properly printed, washed, post-cured, and later on, removed by water. Therefore, we recommend the following properties for designing a 3D-printed mold (Table 1 and Figure 1).

The shown suggestions are based on Cubic Ink's experiences gained in projects with customers and do not represent all possible approaches. Users are invited to analyze and adapt the entire process for their purposes and needs.

Table 1: Recommendations for mold construction.

Property	Preference
Cylinder Form	Better force distribution, less risk of cracking
Two-Piece Form	Improved printability and easier post-processing
Area Maximizing	Accelerated dissolution when exposed to water, reduces swelling
Injection Plat	Better control over the njection process

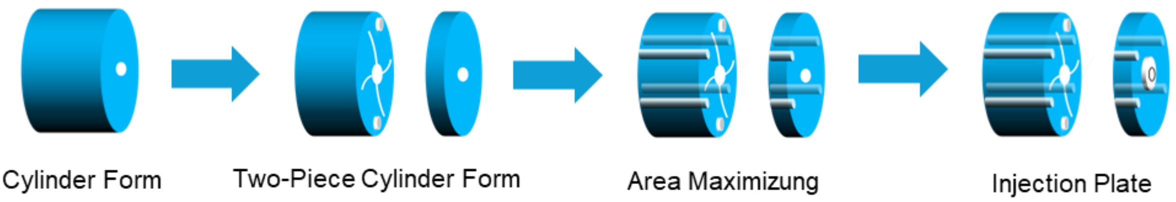


Figure 1: Illustration of the construction process when using water-breakable mold material.

Printing

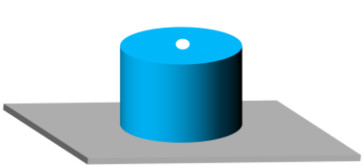
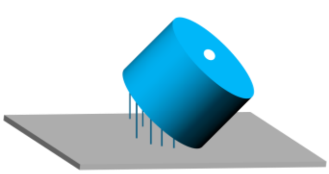
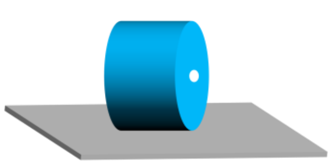
Print Settings

Printed part properties of Cubic Ink Mold materials may vary with printer, print settings, object orientation, part geometry and post-processing. The shown recommendations of printer and print settings are based on Cubic Ink's experiments and experience and do not include all possible processes and feasibility of the material (Table 2 - 5). The processor is welcome to explore the workflow regarding printer and print settings since Mold 400 and 2200 VP is compatible with a broad range of LCD, DLP and mSLA machines with irradiation wavelength of 385 or 405 nm. Nevertheless, Cubic Ink supports and customizes the processing guidelines together with their partners.

With respect to the object orientation on the platform, the following requirements are important:

- There are different possibilities how to arrange the object on the printer platform. The object can be printed on the ground plate (0°), perpendicular (90 °), and angled to the platform (between 0° and 90°). Each orientation has its advantages/disadvantages which are summarized in Table 2.
- Avoid support structures inside the mold. These are hardly removable and affect the surface of the final product.
- Supports on the outside of the mold are generally uncritical. In doubt, it is better to print more than less support structures.
- Avoid a "suction cup" effect. This phenomenon occurs when air is entrapped between building plate, resin and printed molds. This effect causes higher detachment forces leading to printing errors and inaccuracies. Small holes and channels are usually sufficient to avoid this problem.
- Depending on the geometry and later application, layer thicknesses between 50 µm and 100 µm are feasible.
- The resin is highly reactive, therefore only short exposure times necessary.

Table 2: Possible orientations of the mold on the building platform of the printer with its advantages and disadvantages.

On Ground Plate (0°)	**Angled (1 - 89°)**	**Perpendicular (90°)**
		
• Fast to print • No steps on vertical edges • Generally higher layer thickness possible	• Mainly every geometry is printable • Usually, easy removal from building plate and no risk that objects fall off	• No steps along vertical edges • Generally higher layer thickness possible
• Can become difficult to remove from building plate • Suction cup effect likely not avoidable	• Printing of steps along the edges (requires thinner layers)	• Longest print time • Difficult to print due to strong overhangs ("printing in the air") • Risk that object fall off from the building plate

Printing

General Curing Parameters

In Table 3 different curing characteristics are presented. The necessary critical energy as well as the penetration of depth indicate the reactivity and curing in depth abilities of the liquid resin.

Table 3: Curing Parameters measured at Cubic Ink for Mold 400 VP.

Measurement	Mold 400 VP			
405 nm, 8 mW/cm^2:				
E_c [mJ/cm^2]	1.00			
D_p [mm]	0.18			
Thickness after 0.4 s of exposure [mm]	0.19			
Thickness after 2 s of exposure [mm]	0.52			
385 nm, 11 mW/cm^2:				
E_c [mJ/cm^2]	1.13			
D_p [mm]	0.10			
Thickness after 0.4 s of exposure [mm]	0.16			
Thickness after 2 s of exposure [mm]	0.37			
x-y-Compensation [%]	1.30[1]	1.80[2]	1.6[3]	1.10[4]
z-Compensation [mm]	<0.01[1]	0.10[2]	-0.05[3]	-0.10[4]
Printable overhangs [°]	up to 35[1]	up to 25[2]	up to 25[3]	up to 30[4]
Minimal wall thickness unsupported [mm]	0.4[1]	0.4[2]	0.6[3]	0.2[4]
Minimal wall thickness supported [mm]	0.4[1]	0.4[2]	0.6[3]	0.4[4]
Minimum pin thickness [mm]	1.0[1]	1.0[2]	1.0[3]	0.5[4]
Minimum hole thickness vertical [mm]	0.5[1]	0.5[2]	0.5[3]	1.0[4]
Minimum hole thickness horizontal [mm]	1.0[1]	0.5[2]	1.0[3]	2.0[4]

[1]Measured with samples printed and cured via Asiga Pro 4K (DLP 385 nm, 11 mW/cm^2, 50 µm) and 2x 30 min Prusa CW1S (LED, 405 nm); [2]Measured with samples printed and cured via Asiga Pro 4K (DLP 385 nm, 11 mW/cm^2, 100 µm) and 2x 30 min Prusa CW1S (LED, 405 nm); [3]Measured with samples printed and cured via Formlabs Form 4 (LCD 405 nm, 5.5 mW/cm^2, 50 µm) and 2x 30 min Formlabs Form cure L @ 80°C (LED, 405 nm); [4]Measured with samples printed and cured via Formlabs Form 4 (LCD 405 nm, 11 mW/cm^2, 100 µm) and 2x 30 min Prusa CW1S (LED, 405 nm). For more details, please contact us.

Printing

Print Settings

Table 4: Suggested curing times depending on wavelength, color, printing thickness and intensity of light source for Mold 400 VP.

Wavelength	Color	Layer thickness [µm]	11 mW/cm²	8 mW/cm²	5 mW/cm²	2 mW/cm²
385 nm	Uncolored	50	0.26 s	0.36 s	0.57 s	1.42 s
	Uncolored	100	0.29 s	0.43 s	0.69 s	1.73 s
405 nm	Uncolored	50	-	0.18 s	0.28 s	0.71 s
	Uncolored	100	-	0.25 s	0.39 s	0.98 s

Mold materials for injection molding were tested on several printers such as

Prusa SL1S Speed (LCD, 405 nm, 2 mW/cm²), Phrozen 8K Mighty (LCD, 405 nm, 2 mW/cm²), Phrozen 8K Mega S (LCD, 405 nm, 3 – 5.6 mW/cm²), Asiga Pro 4K80/ Max 2 (DLP, 385 nm, 2 - 11 mW/cm²), Formlabs Form 4 (LCD, 405 nm, 2 - 11 mW/cm²), Nexa XiP (LCD, 405 nm, 2 – 5.5 mW/cm²), Rayshape Raise3d DF2 (DLP, 405 nm, 3 mW/cm²), Elegoo Satrun (LCD, 405 nm, 2 – 3 mW/cm²), Anycubic Photon Mono 4 (LCD, 405 nm, 3 mW/cm²), MiiCraft alpha (DLP, 405 nm). For more information, please contact us.

Table 5: Examples of print settings at Cubic Ink for Mold 400 VP Uncolored.

Printing system	Color	Layer thickness [µm]	Exposure time bottom layer [s]	Exposure time default layer [s]
Prusa SL1S Speed (LCD, 405 nm, 2 mW/cm²)	Uncolored	50	8.00	1.00
Formlabs Form 4 (LCD, 405 nm, 5,5 mW/cm²)	Uncolored	50	0.45	0.30
	Uncolored	100	0.72	0.36
Nexa XiP (LCD, 405 nm, 2.5 – 5.5 mW/cm²)	Uncolored	50	5.00	2.00
Asiga Pro 4K80 (DLP, 385 nm, 11 mW/cm²)	Uncolored	50	1.00	0.26
	Uncolored	100	1.00	0.31

Washing

Removing & Washing

- Washing with isopropyl alcohol (IPA) and/or Ethanol up to 5 min
- As an alternative Resin Cleaner 400 can be used up to 5 min
- Ultrasonic bath or adequate mixing equipment is beneficial
- Please, make sure that every part of the object is free of resin. For small and internal channels using a washing bottle is beneficial.
- Depending on the geometry, the procedure can be repeated
- An illustration is shown in Figure 2.

Cleaning

- Treatment with compressed air, especially in internal thinner channels, recommended

Washing in a stirred Isopropanol bath

Rinsing channels and cavities with an Isopropanol wash bottle

Drying the mold with compressed air

Figure 2: Washing of the mold after printing.

Drying

- Let dry at ambient conditions for at least 10 min

Post-Curing

Mold materials for injection molding need to be post-cured to reach its final material properties. The post-cure used on the TDS of Mold 400 VP (Version 2) contained 30 min UV-treatment via Prusa CW1S (LED, 405 nm). Other examples of post-curing are shown in Table 6 to emphasize different effects of UV-curing chambers, wavelengths, intensities, time and additional thermal post-cure.

Mold 400 VP is post-cured via
- UV-cure is necessary.
- Turn the mold to avoid shadowing
- After removal from the post-curing unit, the molds are usually warm to lukewarm and need a couple of hours to completely cool down to room temperature

- Common UV LED chamber with 365 – 405 nm wavelength or flash-light devices can be used
- Time depending on thickness and diameter.:
  - For the shown cylinder (e.g. Figure 1 and 2, Ø = 80 mm, h = 30 mm), we recommend 2 x 30 min.
  - LED post-curing exceeding 120 min is generally not useful
- If possible, use vacuum or nitrogen atmosphere
- Monitore the temperature in the post-cure chamber:
  - Strong heat build up may lead to deformation
  - High energy sources with low wavelength (e.g. Hg-lamps) can cause object deformation

Table 6: UV post-processing carried out at Cubic Ink for Mold 400 VP (printed with 50 µm).

Post-Process	E-Modulus [GPa]	Tensile strength [MPa]	Elongation at break [%]
2 x 30 min Formcure L, 30 °C	1.8	39	48
2 x 30 min Formcure L, 60 °C	2.1	46	33
2 x 2000 flashes Otoflash, N_2	1.9	42	46
2 x 30 min Prusa	2.0	43	36
2 x 30 min Phrozen	1.8	38	50

Formlabs Formcure L = LED, 375 and 405 nm; NK Optik Otoflash G171-6 = light-flashes, 350 – 550 nm, N_2; Prusa CW1S = LED 405 nm; Phrozen = LED 405 nm. Tensile testing DIN EN ISO 527-1 5A-specimens, 5 mm/min, 23 °C; HDT B DIN EN ISO 75, all specimens printed vertically.

Injection Molding

General Information

Mold materials for injection molding are compatible with a wide range of typical filling materials. Some examples are shown below. The list is continuously expanded according to customer feedback. Potentially higher filling grades are possible.

- Polyethylene
- 2-Polypropylene (with up to 36% GF)
- Polyamide-6 (with up to 40% GF)
- Polyamide-12
- PVC
- PEEK (up to 30% CF)
- PPS (up to 80% CF)
- Polycarbonate (up to 20% GF)
- Compounds from recycled/renewable feedstock such as ARBOFILL®

Procedure

The shown suggestions are based on Cubic Ink's experiences gained in projects with customers and do not represent all possible approaches. Users are invited to analyze and adapt the entire process for their purposes and needs.

To place the mold into the injection molding machine, a tool holder for the mold made of stainless steel or aluminum is necessary (e.g. Figure 3).

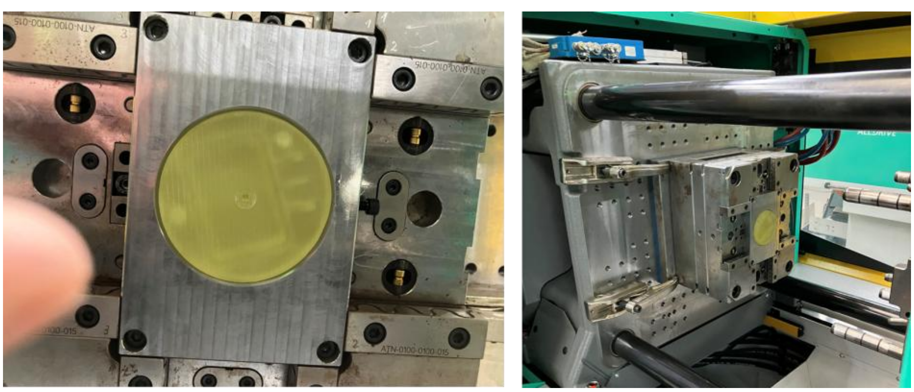


Figure 3: Printed mold placed in a holder which is fixed in an Arburg injection molding machine.

Please note that the mold is **just placed** into the holder without screw connection or related fixing. Therefore, it is important that the mold perfectly fits to the holder. Typical injection molding parameters (injection temperature, pressure, material feed, holding pressure) are strongly dependent on geometry and filling material. When our Mold series is used for the first time, some iteration steps to identify the optimal conditions are necessary to find the best parameter setting. In contrast to metallic molds, the material feed can be run slower in our printed molds due to their lower heat conductivity – a setting which reduces the risk of cracking.

After the injection process, the entire filled mold is removed and the next one can be injected, enabling a very short cycle time.

Mold Removal

General Information

The last step in the process is the removal of the final part from mold. The highlight of our mold materials is their very high-water affinity so that the molds break away when exposed to water and releases the object. There are several settings to accelerate this removal process, which are summarized in Table 7.

The time it takes until the final part can be removed from the mold depends on several factors (e.g. Cubic Ink® Mold version, geometry and wall thicknesses, dissolution media, temperature, etc.). In the best cases, the material can be removed in a couple of hours. In other cases, this procedure can take up to 2 days.

When placed in a 200 ml aqueous solution of 1% NaOH at 60 °C with constant stirring, approximately 10 hours are required to completely break down 10 mm^3 of cured resin in the form of a cube with 10 mm side length.

However, since the cured resin is water-breakable, it is recommended to remove degraded material at frequent and regular intervals. This allows the removal medium to access deeper and more effectively into the cured resin accelerating the overall degradation process.

Table 7: Recommendations for mold removal.

Parameter	Preference
Temperature	The higher the temperature, the faster the material dissolves. Temperature between 50 - 80 °C are recommended
Stirring	Any flow in the water bath is beneficial, e.g. by using a stirrer, ultrasonic bath, or a combination of both.
Alkalic Media[1]	Alkalic aqueous media significantly increases the water solubility and accelerates the de-molding process. Therefore, our Mold Remover 100 is the ideal ready-to-use solution for the removal process for all our Mold prototypes.
Part Geometry	Components with restricted contact between the cured resin and the removal medium, such as tubes, require longer demolding times
Part Size and Thickness	
Post-curing of the Parts	

[1]Please note: When using alkalic media, make sure that every material in contact with the solution is compatible with it. This is in particular important for base metals.

Mold Removal

Disposal of Wash Water

After the final part is taken out, the remaining water contains solid polymer particles as well as dissolved Mold material. As a first disposal step, we recommend filtering off the solids. These can then be disposed via the standard solid waste, if they are not contaminated with other substances.

Concerning the correct waste code of the remaining water, the following wastewater parameters were determined through an external institute to give you an orientation on the correct disposal (Table 8). As these values are concentration- and saturation-dependent, the following extract is based on a wash water sample in which 3.00 g printed, and post-cured Mold 400 VP was exposed to 1.00 L water (demineralized) for 24 h at 23 °C under stirring.

Please note: Cubic Ink cannot provide you with binding instruction on the removal of the wash water. The threshold values under which process water can disposed via the normal wastewater depend on the requirements provided by your wastewater disposal contractor and differ by region and particular industry. The analysis provided is a useful basis to be discussed with your EH&S department and/or waste contractor to decide about the final disposal.

Table 8: Wastewater analysis of printed and cured Mold 400 VP (3.00 g) in 1.00 L water. Exposure time: 24 h under stirring, temperature: 23 °C.

Test Method	Parameter	Value	Norm
Physical-chemical Parameters	pH Value	6.8	DIN EN ISO 10523
	Conductivity (25 °C)	608 µS/cm	DIN EN 27888
Sum Parameters	Chemical Oxygen Demand, homogenized	2.80 mg/L	DIN EN 38409-41
	Total Organic Content (TOC)	730 mg/L	DIN EN 1484
	Total Nitrogen bounded (TNb)	70 mg/L	DIN EN 12260
Biotests	Fish Egg Test (GEi Value)	32	DIN EN ISO 15088
GC-MS Screening	Volatile, aromatic hydrocarbons	<0.3 µg/L	Internal Method
	Volatile, halogenated hydrocarbons	<0.3 µg/L	Internal Method
	Polycyclic, aromatic hydorcarbons	<0.3 µg/L	Internal Method
	Phtalates	<0.3 µg/L	Internal Method
	Aliphatic hydrocarbons	<0.3 µg/L	Internal Method
	Trimethylbenzoic acid	1600 µg/L	Internal Method

Values confirmed by ongoing analysis.

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