

Investment Casting with PolyCast™

1. Overview

PolyCast™ is an entirely new 3D printing filament designed specifically for investment casting applications. This document provides the basic information regarding the printing and post-processing of the material, as well as a practice guide for investment casting processes using 3D printed PolyCast™ patterns.

2. Brief introduction

Investment casting produces metal parts with excellent surface finish and dimensional accuracy. This manufacturing process is compatible with a large number of metals & alloys, such as steel, stainless steel, aluminum alloy, bronze, etc.

Traditional investment casting processes utilize injection molded wax patterns. The tooling required is both time- and cost-intensive.

3D printing has been increasingly used as an alternative method to produce investment casting patterns, especially for small-volume production runs, as it cuts down both the cost and lead time significantly by eliminating the tooling process. In addition, 3D printing enables a larger design freedom as the technology can afford much greater geometric complexities than the injection molding process.

PolyCast™ is an entirely new 3D printing filament, designed specifically for investment casting applications. It enables the use of widely available filament-extrusion based 3D printing technologies (e.g. FDM/FFF) to produce investment patterns.

The key advantages of PolyCast™ include:

- Compatible with Polymaker's Layer-Free™ technology, delivering superior surface quality while minimizing the need for post-processing after casting;
- PolyCast™ burns off cleanly without any residue, enabling defect-free metal parts;
- Can be used on any FDM/FFF printer with excellent printability;
- Lower cost compared to other 3D printing technologies (e.g. SLA/DLP/SLS).



Figure 1. Rapid production of metal parts using PolyCast™ and 3D printing



Polishability



No Ash



Excellent
Printability



Low Cost

Investment Casting with PolyCast™

Comparison between conventional wax-based investment casting and PolyCast™

	Conventional investment casting	Investment casting with PolyCast™
Tooling cost	\$ 10,000 – 1000,000	\$ 0
Lead time	> 5 weeks	< 2 weeks

3. Process Overview



The video of PolyCast™ can also help you understand this process. (<https://www.youtube.com/watch?v=Un3dpy9Og5Q>)

4. 3D printing with PolyCast™

PolyCast™ (available in both 1.75 and 2.85 mm diameters) can be used on almost any filament-extrusion based 3D printer that allows 3rd party materials. The material is engineered to offer excellent printability with easy support removal. Below is a quick guide to get you started with printing PolyCast™.

4.1. Prepare your 3D printer

PolyCast™ patterns can be produced on the vast majority of the filament-extrusion based 3D printers in the market. Any printer compatible with printing PLA is expected to work with PolyCast™. The following printers are some examples which have also passed Polymaker's long-term test:

- Makerbot Replicator+ / Mini+ / Z18 / 2 / 5th generation / Mini
- Ultimaker 3 / 2+ / 2 GO / Original+
- LULZBOT TAZ 6 / TAZ 5 / MINI

- MakerGear M3 / M3 independent Dual / M2 / M2 Dual
- BCN3D Sigma / +
- Zortrax M300 / M200
- Raise3D N2 / N2 Plus
- CEL Robox
- MASS PORTAL Pharaoh XD 20 / Pharaoh XD 30 / Pharaoh XD 40
- FLASHFORGE Creator pro / Dreamer
- XYZPrinting da vinci Pro
- 3D Platform

4.2. Slicer settings

Below are recommended slicer settings for printers with standard 0.4 mm nozzles. The parameters can be modified to suit any particular printer set up.

Parameter	Recommended Setting
Nozzle temperature (°C)	200 – 230
Build surface material	Glass, Blue Tape, BuildTak®
Build surface treatment	Not required if heated to 60-70 °C; Or apply PVA glue to the build surface
Build plate temperature (°C)	0 - 70
Model cooling fan	Turned on
Printing speed (mm/s)	40 – 90
Raft separation distance (mm)	0.1 - 0.14
Retraction distance (mm)	1 – 3
Retraction speed (mm/s)	30 – 40
Recommended environmental temperature (°C)	20 – 30
Threshold overhang angle (°)	60
Recommended support materials	S02N (PI), or PVA

Other comments :

- Print patterns with minimal infill (e.g. 10%) and number of shells (2-3). This facilitates the pattern burnout process, and can prevent potential damage to the ceramic shell.
- Apply shrinkage compensation to the STL file. The dimensional change of printed PolyCast™ patterns during the casting process is negligible, so you only need to consider the shrinkage of metal from the molten to solid state. Modify the size of the model by the metal/alloy-dependent compensation factor, which is typically between 1.007-1.030. For example, the compensation factor for steel is 1.025-1.030. Therefore if the expected dimension of the metal part is 1 m, the dimension of printed patterns should be 1.025-1.030 m.

- Pattern designs for traditional wax processes may be used directly for 3D printing, and it is ideal for producing small numbers of prototypes of parts that will eventually be mass manufactured using the wax process. However for making end-use parts, users are encouraged to “design for 3D printing”, i.e. take advantage of 3D printing and optimize the part geometry to improve both printing quality and efficiency. For a complete guide, check out this article by 3D Hubs: <https://www.3dhubs.com/knowledge-base/how-design-parts-fdm-3d-printing>
- Choose a suitable orientation to place the model on the printer platform, to minimize support structure as much as possible. It is helpful to improve both printing efficiency and surface finish.
- Use a typical layer height of 0.1-0.2 mm. This ensures a reasonable spatial resolution and facilitates the post-processing.

4.3. Handling and storage

PolyCast™ is sensitive to moisture. Please keep filament under dry conditions (relative humidity of no more than 20%) during storage and utility. One good solution is to use Polymaker's PolyBox™ (purchased separately).

Moisture within the patterns is not acceptable because it will affect the pattern burnout process, which increases the possibility of failure from shell cracking. To dry the printed patterns, expose the patterns to well-circulated hot air at 50 °C for at least 1 hour.

5. Post-processing of 3D printed patterns

The surface finish of patterns will have a strong effect on the casting process as well as the surface finish of final metal parts, so it is very important to polish the surfaces of patterns through post-processing.

5.1. Layer-Free™

PolyCast™ is compatible with Polymaker's Layer-Free™ technology, which is the recommended technology for post-processing 3D printed patterns. The technology works by exposing the printed model to a dense mist of tiny (< 10 µm) alcohol droplets, which are absorbed locally onto the surfaces of the printed model and subsequently make them smooth (with layer lines no longer visible), while preserving macroscopic dimensional accuracy. The process can be done seamlessly using Polymaker's desktop machine, the Polysher™ (purchased separately).



Figure 2. PolyBox™ - the perfect solution for storing 3D printing filaments



Figure 3. Polish the PolyCast™ pattern by Polysher™

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The polished part will exhibit fully sealed surfaces with a smooth and glossy finish. This is critical for the success of investment casting, for a number of reasons:

- The porous surfaces on many FDM/FFF parts can result in penetration of the slurry that leads to defects in final metal parts. Fully sealing the surface eliminates this problem.
- A smooth surface finish facilitates the slurry coating process. In contrast, a rough surface with layer lines can lead to issues such as trapped air bubbles, which in turn can cause defects in final metal parts.
- The smooth surface finish ensures high surface quality of the final metal parts and minimize the need for post-processing (e.g. surface polishing).

Follow the steps below to polish a printed PolyCast™ pattern (using the Polysher™)

STEP 1 (optional): Use sand paper (800-grit or similar) to remove any major seams or surface defects of the printed pattern. Remove dust and debris.

STEP 2: Use the Polysher™ to process the printed pattern. Follow the correct procedure when operating the Polysher™. Depending on the size, ambient temperature, alcohol concentration, etc., it may take anywhere between 20-60 minutes to polish the pattern. Place the part on the Polysher™ platform in a way that allows maximum and even exposure of all surfaces to the alcohol mist. It is recommended to “hang” the part by attaching it to a wire or similar material on a stand, or raise the bottom using a base with small contact area.

STEP 3: Allow the print to dry for 20-30 minutes. Inspect the print. Repeat STEP1-2 if more polishing is needed.

STEP 4: Place the polished pattern in a vacuum (preferred) or convection oven at 40 °C for at least 1 hour to ensure complete solvent evaporation and surface hardening.

Investment Casting with PolyCast™

If access to a Polysher™ is not available, or the pattern exceeds the maximum size of the Polysher™, two alternative polishing techniques can be considered: dip polishing and spray polishing. Unlike using the Polysher™ both techniques require certain extent of practice to accumulate enough experience and achieve good results.

The following are recommended steps for dip and spray polishing:

5.2. Dip Polishing

STEP1 (optional): Use sand paper (800-grit or similar) to remove any major seams or surface defects of the printed pattern. Remove dust and debris.

STEP2: Attach a wire or similar material to suspend the prints.

STEP3: Immerse the print in isopropyl alcohol or ethyl alcohol for 5-10 seconds typically. You can use multiple short immersions to get stronger polishing effect.

STEP4: Allow the print to dry for 20-30 minutes. Inspect the print. Repeat STEP1-4 if needed.

STEP5: Allow the part to rest in a vacuum(preferred) or convection oven at 40 °C for 1 hour to ensure complete solvent evaporation and surface hardening.

5.3. Spray Polishing

STEP1 (optional): Use sand paper (800-grit or similar) to remove any major seams or surface defects of the printed pattern. Remove dust and debris.

STEP2: Attach a wire or similar material to suspend the print or put it on a base with small contact area.

STEP3: Spray isopropyl alcohol or ethyl alcohol on the print surface.

STEP4: Allow the print to dry for 20-30 minutes. Inspect the print. Repeat STEP1-4 if needed.

STEP5: Allow the part to rest in a vacuum(preferred) or convection oven at 40 °C for 1 hour to ensure complete solvent evaporation and surface hardening.



Figure 4. Dip the PolyCast™ pattern into isopropyl alcohol



Figure 5. Spray isopropyl alcohol on the PolyCast™ pattern

6. Investment casting process with PolyCast™ patterns

In most cases PolyCast™ patterns can be used in a similar way as traditional wax patterns, with no or minimal modification to the casting process. However, in order to achieve high success rates and consistent results, we still recommend that you follow or at least start with the following “best practice” guide.

6.1. Build casting tree

The casting tree can be built using the same method as wax patterns. PolyCast™ patterns adhere well to the wax.

Additional vents/gates may be added to promote air flow during the burnout process. Another effective way to promote air flow is to drill through the outer shell of the pattern at the gate location.

6.2. Make ceramic shell

Build up the ceramic shell around the casting tree by using the standard process of the foundry. Use silica sol/gel, colloidal silica, etc. as slurry systems for Polycast™ (avoid using sodium silicate). The number of coatings can be between 4-9 and varies by foundries (also by parts). We recommend 5-6 coats (no less than 5) for PolyCast™ as this has been found to produce the most consistent results. If the patterns contain some fine structures (e.g. turbine blades), we recommend 7-9 coats to prevent any potential risk of shell cracking.

6.3. De-waxing

Use high temperature steam to remove the wax tree. The PolyCast™ will still remain in the ceramic shell (the pattern may soften or deform) which is normal – it will be burned off in the sintering process. You can choose to skip the de-waxing step entirely if recycling the wax is not a priority; in this case the wax will simply be burned off in the kiln together with PolyCast™.

6.4. Sinter ceramic shell and burnout

Heat the kiln to 1100-1200 °C for an extended period of time (up to 40-60 min) to simultaneously sinter the ceramic shell and burn out the PolyCast™ patterns. The optimum burnout temperature and time may be determined by each foundry for the metal/part to be produced and the specific kiln or furnace used.



Figure 6. Adhere the PolyCast™ pattern to the wax tree



Figure 7. Make the ceramic shell



Figure 8. Sinter the ceramic shell and burnout



Figure 9. Rinse the shell

6.5. Rinse shell

Rinse the ceramic shell (after cooling down to ambient temperature) by water to remove any residual ash that may still be present. We recommend the rinse step just as a “safe” option for foundries to get started, in case the burnout process is not yet optimal which can leave small amount of ash in the shell. Once the foundry is more experienced with the process they can skip the shell rinsing step upon their choice. In our experience foundries can get excellent results without this step.

6.6. Cast

Once the ceramic shell is fully prepared and clean, complete the casting process by following the standard practice for the designated metal/alloy. Steps may include pre-heating the shell, pouring the molten metal/alloy to the shell, allowing the shell to cool, removing the shell, cutting off gates, machining, heat treatment, etc.



Figure 10. Pour the molten stainless steel into the shell

7. Critical success factors

7.1. Pattern

- Use minimal infill and number of shells
- Maintain the filament dry
- Dry patterns thoroughly before making ceramic shell

7.2. Ceramic shell

- Use silica sol/gel or colloidal silica
- Use at least 4-6 slurry coats

8. Printing and casting service

You can contact 3DHubs (<https://www.3dhubs.com>) if you need such service.

9. Safety

Observe manufacturer's recommendations for safety, material handling and storage, before using any chemical solvent and instrument in polishing process. This information can be found in the Safety Data Sheet (SDS).

10. Contact

Please contact us through support@polymaker.com



PolyCast™

For other languages, please visit
www.polymaker.com

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My first print

1) Prepare the gcode

Download the MyFirstPrint.stl on www.polymaker.com

Load the stl file in your favorite slicer.

Enter the correct settings for PolyCast™;

Property	Value
Nozzle temperature	190°C - 220°C
Bed temperature	25°C - 70°C
Nozzle speed	40mm/s - 60mm/s
Cooling fan	ON
Layer height	0.1
Infill	20%
Number of outlines (shell)	3
Top/Bottom layers	4

2) Prepare the printer

- Clean the build plate and prepare it with the right surface:

We recommend to print **PolyCast™** on glass with glue, painters tape or PEI sheet with glue.

- Level the build plate.

- It is recommended to clean the nozzle when you change the material to prevent partial clog.

Note: It is recommended to place the printer in a well ventilated area.

3) Prepare the filament

- Carefully open the resealable bag, remove the spool and close the bag back to preserve the desiccant bag.
- It is highly recommended to store **PolyCast™** in the **PolyBox™** to prevent moisture absorption which will lower the quality and the mechanical properties of the print.
- Load the filament in your printer and wait until you have a consistent extrusion.
- At the end of the print, make sure to correctly store the filament back in the resealable bag if you are not using the **PolyBox™**.

4) Start the print

When the print begins, make sure the first layer is correctly laid down and sticking well to the bed before leaving the printer to finish the print. If you hear popping sounds and notice that the surface quality of your print is uneven or the color is not consistent, the filament has absorbed too much moisture. You can dry **PolyCast™** at 60°C for 12 hours and start the print again.

5) Post process

PolyCast™ can be polished with alcohol (IPA) to obtain a smooth surface. We recommend the **Polysher™** for the polishing process.

PolyCast™ can also be wet sanded to obtain a smoother surface.

PolyCast™ can be dipped in hot water (above 80°C) and be reshaped. The model will then harden back in its new shape.



PolyCast™ is a filament designed to produce investment patterns for investment casting applications. 3D printing significantly cuts down both the cost and lead time by eliminating the tooling process.

Available colors: 

Drying settings

60°C for 12h

Diameter accuracy (2.85/1.75 mm):

70%	is within	+/- 0.01
97%	is within	+/- 0.02
99%	is within	+/- 0.03

Weight accuracy:

600g	+/-	20g
750g	+/-	20g
1000g	+/-	30g

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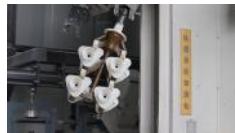
1. Build casting tree

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2. Make ceramic shell

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3. De-waxing

Use high temperature steam to remove the wax tree. The **PolyCast™** will still remain in the ceramic shell. You can choose to skip the de-waxing step entirely if recycling the wax is not a priority; in this case the wax will simply be burned off in the kiln together with **PolyCast™**.



4. Sinter ceramic shell and burnout

Heat the kiln to 1100-1200 °C for an extended period of time (up to 40-60 min) to simultaneously sinter the ceramic shell and burn out the **PolyCast™** patterns. The optimum burnout temperature and time may be determined by each foundry for the metal/part to be produced and the specific kiln or furnace used.



5. Rinse shell

After cooling down to ambient temperature, rinse the ceramic shell with water to remove any residual ash that may still be present. We recommend the rinse step just as a “safe” option for foundries to get started. Once the foundry is more experienced with the process they can skip the shell rinsing step upon their choice. In our experience foundries can get excellent results without this step.



6. Cast

Once the ceramic shell is fully prepared and clean, complete the casting process by following the standard practice for the designated metal/alloy. Steps may include pre-heating the shell, pouring the molten metal/alloy to the shell, allowing the shell to cool, removing the shell, cutting off gates, machining, heat treatment, etc.



Product Families



PolyLite™

ABS, PETG, PLA, PC

PolyLite™ is a family of 3D printing filaments made with the best raw materials to deliver exceptional quality and reliability. PolyLite™ covers the most popular 3D printing materials to meet your everyday needs in design and prototyping.



PolyMax™

PLA, PC, PETG

The PolyMax™ is a family of advanced 3D printing filaments produced with Polymaker's Nano-reinforcement technology, to deliver exceptional mechanical properties and printing quality.



PolyFlex™

TPU95

PolyFlex™ is a family of high-quality flexible materials. It provides the perfect solution for applications where high flexibility and durability are required.



PolyMide™

CoPA

PolyMide™ is a family of Nylon/polyamide based filaments. Produced with Polymaker's Warp-Free™ technology, PolyMide™ filaments deliver engineering properties intrinsic to Nylon and ease of printing.



PolyDissolve™

S1

PolyDissolve™ is a family of dissolvable support filaments. This family offers support solution for our portfolio of filaments. It enables a greater design freedom.



Specialty

PolyWood™, PolySupport™, PolySmooth™, PolyCast™

The Specialty family provides unique filaments from Polymaker to unlock new 3D printing applications.

Technologies

JAM-FREE™

Jam-Free™ technology improves the heat stability of Polymaker's PLA filaments with softening temperatures over 140 °C. As a result, Polymaker's PLA filaments show minimal softening in the "cold end" and can melt rapidly once entering the heating zone, leading to excellent printing quality with zero risk of nozzle jams.

Regular PLA



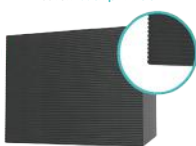
With Jam-Free™



Regular Nylon



With Warp-Free™



WARP-FREE™

Warp-Free™ technology enables the production of Nylon-based filaments that can be 3D printed with excellent dimensional stability and near-zero warpage. This is achieved by the fine control of micro-structure and crystallization behavior of Nylon, which enables the material to fully release the internal stress before solidification.

ASH-FREE™

Ash-Free™ technology allows Polymaker's filament which has been designed for investment casting to burn off cleanly without any residue, enabling defect-free metal parts. 3D printing has been used to produce investment casting patterns as it cuts down both the cost and lead time for small-volume production runs.

Without Ash-Free™

Ash content: 0.5%



With Ash-Free™

Ash content: 0.003%



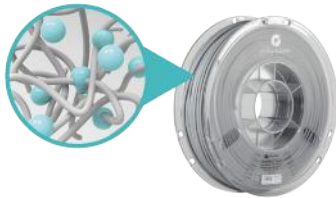
LAYER-FREE™

Layer-Free™ technology involves exposing a 3D printed part to an aerosol of micro-sized alcohol droplets, generated by a rapidly vibrating, perforated membrane called the nebulizer. The aerosol will then be adsorbed by the surface of the 3D printed part and render it smooth and layer-free.

Rough surface



With Layer-Free™



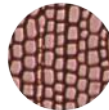
NANO-REINFORCEMENT

Nano-reinforcement technology is applied to produce filaments with excellent mechanical properties and printing quality. It dramatically improves the toughness of the material by increasing its impact resistance.

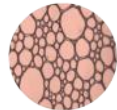
STABILIZED FOAMING™

Stabilized Foaming™ technology is used to produce foamed filaments, whose foam structure can survive the printing process and be inherited by the printed parts. This enables light weight 3D printed parts with unprecedented surface finish.

Wood



Stabilized Foaming™



Hardware

Polymaker offers 3D printing accessories to optimize the user experience with their filaments.

PolyBox™

PolyBox™ is a dry storage box designed to provide the optimum environment for 3D printing filaments. The PolyBox™ is compatible with all 3D printers and can house two 1kg spools or one 3kg spool.



Polysher™

The Polysher™ is a desktop post processing unit designed to remove layer lines from PolySmooth™ and PolyCast™ prints. The Polysher™ uses Polymaker's Layer-Free™ technology to create a fine mist of alcohol which evenly smooths the model.



About Polymaker

Who We Are?

Polymaker is an international team passionate about 3D printing. We produce the very best 3D printing materials by controlling every stage of production. With a diverse portfolio of materials ranging from high performance plastics to unique aesthetic solutions, Polymaker will continue to add cutting edge materials to its ever-growing portfolio.

Mission & Vision

Our mission is to create the best in class when it comes to 3D printing materials. We believe that materials are the enabling factor which will realise 3D printing as a final production tool. Our high performance materials offer solutions that will develop 3D printing into a mainstream manufacturing method.

Locations

Polymaker is a global company head-quartered in Shanghai. With distribution centers located in North America, Europe & Asia, our materials have penetrated every corner of the globe. Our worldwide presence is closely managed through our relationships with our local distributors and resellers. Polymaker is a regular exhibitor at 3D printing exhibitions on 4 continents.

Research & Development

At the core of Polymaker is our research & development laboratory, this is where all our materials are formulated and fine-tuned from the ground up to create the best in class 3D printing materials. Our precision testing equipment combines the latest advancements in technology to ensure we are ahead of the game.

Quality Control

Polymaker implements a rigorous quality control check on all materials. Utilizing our state of the art technology, we measure both the roundness and diameter of our filaments many thousand times a second, monitoring our processes with strict tolerances. We also have a number of processes and technologies that set apart Polymaker materials.

Contact us

For any inquiries or technical support,
please contact: support@polymaker.com

The information provided in this document is intended to serve as basic guidelines on how particular product can be used. Users can adjust the printing conditions based on their needs and actual situations. It is normal for the product to be used outside of the recommended ranges of conditions. Each user is responsible for determining the safety, lawfulness, technical suitability, and disposal/recycling practices of Polymaker materials for the intended application. Polymaker makes no warranty of any kind, unless announced separately, to the fitness for any particular use or application. Polymaker shall not be made liable for any damage, injury or loss induced from the use of Polymaker materials in any particular application

