WHITE PAPER

Silicone Molding For Product Design

Compression molding, two-stage casting, and overmolding. Case studies with OXO, Tinta Crayons, and Dame Products.

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Contents

Introduction

Soft components are a ubiquitous part of most commercial goods, from rubbery feet on a laptop to the ergonomic grip on a pair of scissors. Rubbery materials like polyurethanes, silicones, neoprene, and latex enable product applications from roofing materials to medical devices.

Casting of silicones specifically allows us to expand the properties of 3D printed parts to include bendable and stretchable components using materials readily accessible from hardware stores, art and jewelry supply resellers, and other common retailers.

This report includes case studies from companies **OXO, Tinta Crayons, and Dame Products,** illustrating three different implementations of silicone molding for product design and manufacturing. These techniques include:

- **Compression molding** of silicone putty for gasket prototypes.
- **Two-stage casting** of wax or other hard media for part replication. Silicone casting is used as an intermediate step in the production of a product.
- **Overmolding** for complete silicone encapsulation of prototype hardware.

These three techniques can be used directly, or elements of each borrowed for custom applications. In addition to step-by-step processes, our partners provided industry-proven best practices to execute these techniques with Formlabs Low Force Stereolithography (LFS) printing as a critical step.

FIVE THINGS YOU WILL LEARN:

- Selecting silicone for your application.
- How to use a compression mold for gasket prototyping.
- The best way to replicate a 3D printed master with a flat side.
- How to encapsulate hardware using overmolding.
- Best practices for designing critical features of 3D printed molds.

ABOUT SILICONE

In this report, we cover applications of room temperature vulcanized (RTV) materials in the silicone family. Silicones are a class of polymers that contain the element silicon in their molecular chain, and transform from a liquid (silicone) to a highly flexible and stretchable solid (silicone rubber) when reacted with a chemical catalyst.

In casting and mold-making, RTV silicone rubber captures fine surface details including embossed text. In addition, most castable silicones are not chemically adhesive, and will peel away from 3D printed molds after curing. Mechanical bonding can be achieved by casting onto highly porous surfaces like woven fabric, and in some cases chemical bonding can be promoted with specialized binders.

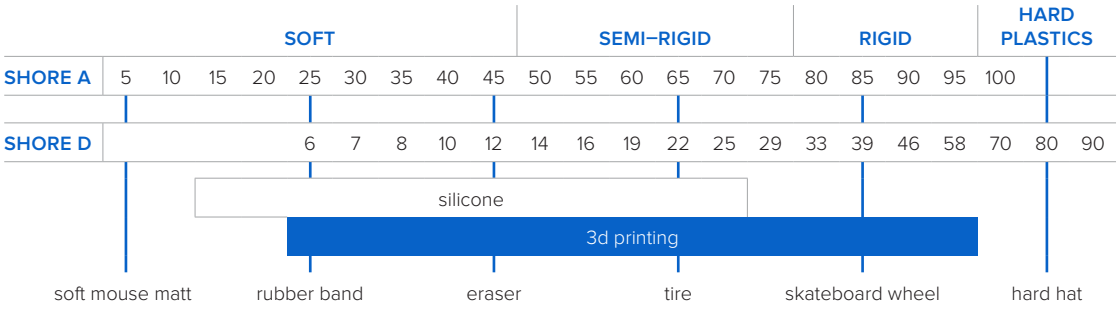
Liquid silicone: Liquid type silicones are typically 2-part or a single part with a small amount of catalyst added. There are two general categories that are readily available. Platinum catalyzed silicones are higher cost but offer superior long-term dimensional stability and very low shrinkage

after full cure. Tin catalyzed silicones are lower cost but less stable over time, and tend to have higher shrinkage rates. Curing time ranges from 10 minutes to several hours.

Silicone putty: This is a two-part putty in which components are blended together in equal amounts by hand. Key applications include mold making for the jewelry industry, however the silicone itself is a good mimic for compression molded gaskets or seals. It has a durometer rating of Shore 40A (see scale below), or a similar hardness to a pencil eraser. This silicone cures quickly in less than 20 minutes, and has zero percent shrinkage.

Skin, mucous membrane, and food safety: Some applications require more sensitivity than others when it comes to contact with the body or contact with food. Always check the materials safety data sheet (MSDS) from the silicone manufacturer to make sure the rubber is safe for your application.

Durometer rating scale: Rubbery materials, including silicone rubbers, can be formulated to a range of hardnesses from extremely soft to extremely firm, as indicated by a specific Shore durometer number. Softer materials are measured on the Shore A scale, and harder materials on the Shore D scale.



Adapted from Meridian Laboratory

We spoke with current Formlabs customers to better understand how they are using their SLA 3D printer to create silicone molds One key takeaway we learned is that there's no one size fits all process, however our users' guidance applies to many applications. While there are always exceptions, most of the advice we collected is broadly applicable to most projects.

Next, we cover basic molding for prototypes, two stage wax casting, and silicone overmolding

Method One:
Quick Silicone Casting for Gasket Prototypes

INTRODUCTION

COMPANY: **OXO**

OXO is a US-based brand that creates ergonomic and practical items for the home, including some iconic kitchen gadget designs. Product developers at OXO use 3D printing for form and function prototyping, but hybrid methods are essential for prototyping rubbery components such as gaskets.

This case study comes from the design of a cocktail shaker gasket. OXO engineers needed to produce a functional prototype that had watertight seals between parts. After testing many available silicones, they determined that compression molding two-part silicone putty Castaldo Quick-Sil was ideal for creating a watertight prototype that mimics the production gasket. In fact, the prototype compression mold is a good representation of method and mold design used in gasket manufacturing.

MATERIALS AND EQUIPMENT:

- McMaster-Carr product 8595K12 Quick-Sil parts A and B
- Formlabs Clear Resin
- Mold Release
- Tabletop vise

STEP-BY-STEP METHOD

1. **Print 2-part mold in Clear Resin:** Printing with 50 µm layer height is recommended for most applications; 25 µm can be used if you are resolving text or other surface textures. Orient parts so critical interior surfaces are free of support marks.

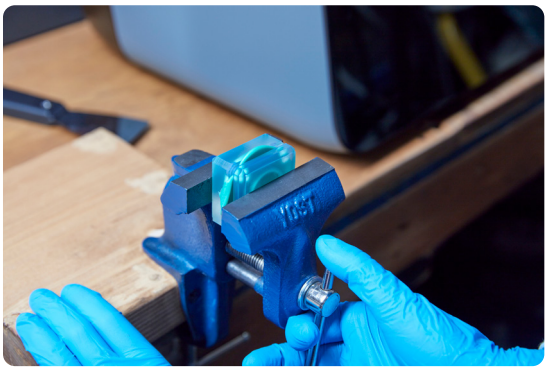
2. **Wash and Cure the mold, and remove supports:** Wash thoroughly with IPA until the parts have a non-tacky finish. We recommend curing at 60˚C for 15 minutes for Clear Resin. It is helpful to sand down support marks so the mold fits squarely in the tabletop vise.

3. **Apply mold release:** Most spray-type mold releases will work for coating interior surfaces.

4. **Mix parts A and B thoroughly:** Mix together equal volumes of parts A and B, and knead by hand. The silicone rubber begins curing after 90 seconds, so the parts should be kneaded for the minimal time necessary to generate a uniform color -- ideally less than one minute.

5. **Stuff silicone into the mold:** The silicone should be compacted into both sides of the mold, being sure to catch all details and crevices. It's ok if slightly too much putty is used; excess material will spill outside the mold.

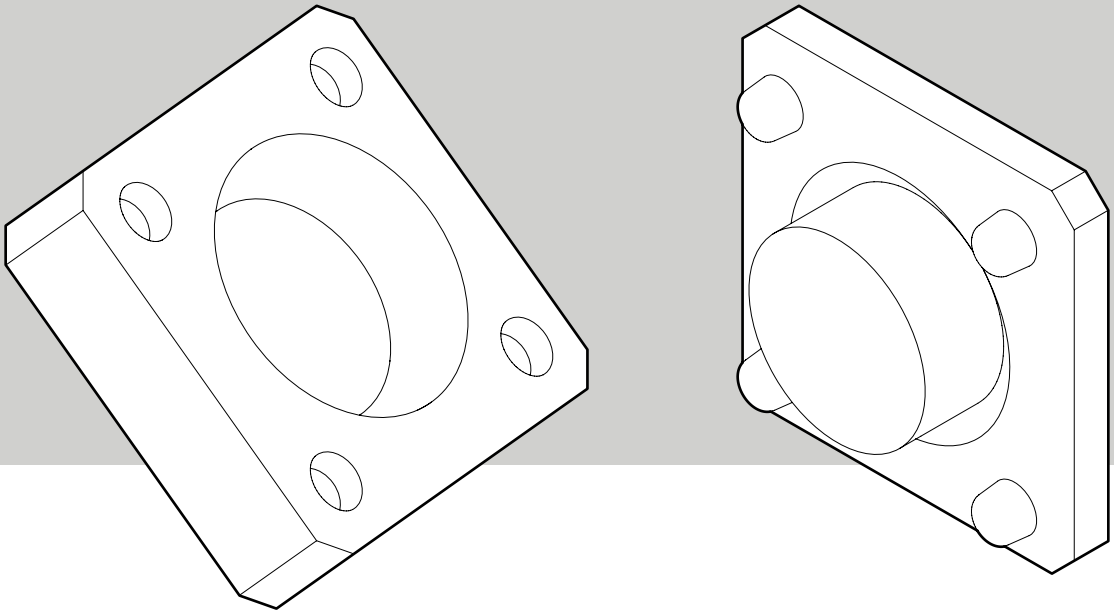
6. **Squeeze mold together using tabletop vise:** The mold should be squeezed perpendicular to the parting line. Note that in compression molds, the parting surfaces don't completely touch until pressure is applied. Close the vise gently until the mold will not close further. The silicone rubber cures completely in 20 minutes.



7. **Demold the prototype:** You can pry apart the mold with the Formlabs spatula or a flat head screwdriver.

8. **Trim and finish the prototype:** There will always be excess material or flashing to trim off where the parts of the mold meet. We recommend using a very sharp hobby blade to do this.

9. **Prepare mold for next casting:** The mold can be re-used multiple times. Reapply mold release and start again from step three.



BEST PRACTICES

a. **Resin selection:** Either Tough Resin or Clear Resin can be used. We recommend using Clear Resin to provide a visual queue for mold filling, however Tough Resin can be used to optimize resistance to clamping pressure. We recommend printing with a 50 µm layer height for a good balance between smooth surface texture and fast printing time. Orient your parts on the build plate so that critical interior surfaces are free of support marks. The outer surface can be polished to a highly transparent finish.

b. **Alignment features:** The four cylindrical bumps and divots at the corners of the mold are used as alignment features to ensure proper registration between the two sides of the mold. Our partner recommends adding 0.1 mm of clearance for alignment features.
In a rotationally symmetric object like this gasket, the alignment features can have identical shape and placement. In other words, the top of the mold can be rotated 90 or 180 degrees, and the gasket shape is not affected. For irregular geometries, a lock and key strategy can be used, in which the shape and placement of the alignment features can only come together in one unique way.

c. **Beveled pry points:** Adding chamfers to the mold edges can make it easier to pry apart the two sides of the mold To pry apart the mold, you can use the spatula that comes with the Formlabs finish kit, or a flat head screwdriver

d. **Mold design:** One of the first design features that you need to consider is the parting line of the mold, or how the two parts of the compression mold come together -- and how they come apart. Our partner at OXO recommends considering how the part will ultimately be manufactured, including what it will take to remove material flashing. In this case, he identified the hard angle on the exterior of the gasket as a convenient place to define the parting line.
Interestingly, draft angles are not a particularly important aspect of this molding process. Notice that an interior divot in the gasket did not need its own parting line. Because the silicone rubber can generously deform during de-molding, many angles can be handled including light undercuts.

Method Two: Two Stage Wax Casting

INTRODUCTION

COMPANIES: **Tinta Crayons, Print My Ride**

Tinta Crayons is a small Australia-based crayon company founded by two mothers of young children. They created their own formula for non-toxic and environmentally friendly wax, and employed silicone molding for small batch manufacturing of crayons with whimsical shapes and high surface detail.

Their process begins with printing a copy of the finished part (the master) with Formlabs standard resin. This part is then replicated in wax by first casting a silicone tray around the master, and then casting the wax into the silicone tray.

The open mold design is well suited for replicating parts that are flat on one side. This method can be extended beyond wax casting to include other end-use materials such as concrete, or two part epoxies. Unlike completely enclosed molds, this method can accommodate casting materials that heat up during curing, physically contract, or physically expand like castable foams.

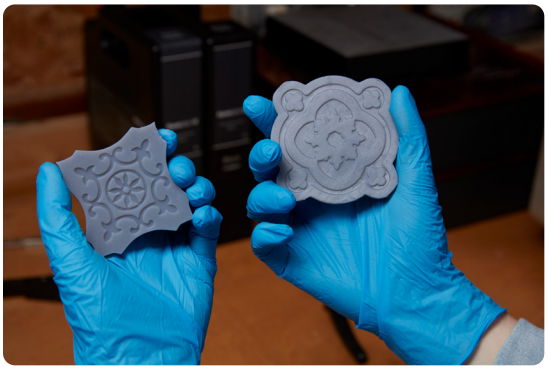
For the following workflow instructions, we interviewed Formlabs Ambassador Matt Schmotzer of Print Your Ride, who implemented the same workflow to create concrete tiles for a kitchen backsplash in his Detroit, MI home.

MATERIALS AND EQUIPMENT

- Two part liquid silicone (OOMOO 30 from Smooth-On)
- Formlabs Grey Resin
- Mold Release
- Wax, concrete, resin, or another end-use material

STEP-BY-STEP METHOD

1. **Print product masters in standard resin.** This is your final part design, which will be replicated in another material. Printing in 50 µm layer height is recommended. Keep the detailed surface free of support marks.



2. **Wash the parts thoroughly with IPA.** Any residual tackiness on the surface can affect the silicone molding process.

3. **Construct a mold housing.** Coated MDF is a popular choice for constructing a containment box for the silicone mold. In our example we simply use a pre-made plastic container. Look for non-porous materials, and a flat bottom.

4. **Layout masters and apply mold release.** Start by lightly misting the inside of the mold housing with mold release. We used Smooth-On Brand universal mold release. Tile the masters inside the box, with the detailed side up. Lightly spray these with mold release, as well. This will need about 10 minutes to fully dry.

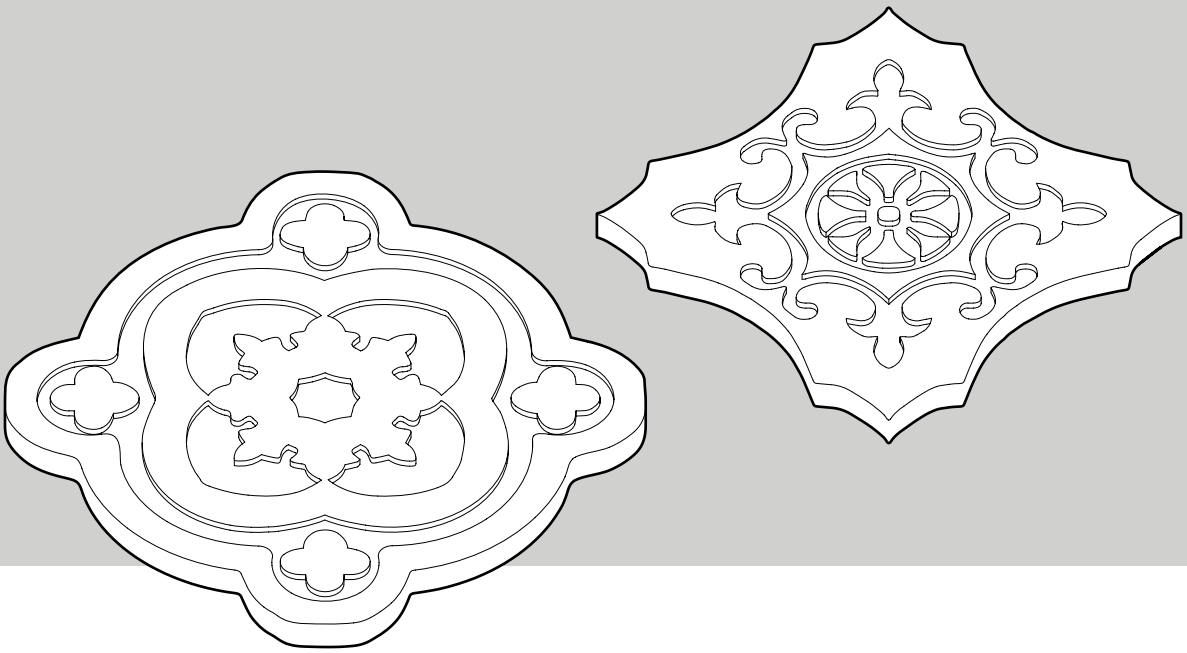
5. **Prepare Silicone:** Mix the silicone rubber according to the package instructions. A vibrating device like a handheld electric sander can be used to remove air bubbles.

6. **Pour Silicone into box:** Gently pour the mixed silicone rubber into the containment box in a narrow stream. Aim for the lowest part of the box first (the base) and gradually come up the contours of the 3D printed part. Cover the part by at least one cm of silicone. The curing process will take from an hour to one day to complete, depending on the silicone type and brand.

7. **De-mold the silicone:** When curing is complete, peel the silicone out of the containment box and remove the masters. This will serve as your ice tray-style mold for casting your end use product.

8. **Cast your part:** Again, it is a good idea to lightly spray the silicone mold with mold release, and dry for 10 minutes. Pour your end-use material (wax, concrete, or something else) into the cavities and allow to cure.

9. **Prepare mold for next casting:** This silicone mold can be used multiple times. Return to step eight to repeat the process.



BEST PRACTICES

a. **Resin Selection:** Standard Resins such as Grey Resin capture high surface detail. Silicone picks up fine details in the surface, including layer lines. While 50 micron layer height provides a good balance between smooth surface and print speed, printing at 25 micron layer height might be appropriate for some aesthetic applications.

b. **Mold Release:** It is important to use this in both stages of your molding process, such as in the creation of the silicone mold, as well as the casting of the end-use part. The Smooth-On brand makes a multipurpose mold release which works well for most applications.

c. **Draft Angles:** Matt used a two degree draft angle for the vertical features in his tiles. However, the silicone molding process is fairly forgiving in this way, and can handle 90 degree angles or light undercuts. If you plan to use the mold multiple times, try to minimize the amount that you need to flex and stretch the mold to release your parts, or seek out a silicone rubber formula with a high tear strength.

Method Three:
Silicone Overmolding for Customer Beta Prototypes

INTRODUCTION

COMPANY: **Dame Products**

Dame Products is a Brooklyn based startup that designs products for the health and wellness industry. Their product line incorporates complex ergonomic geometries, fully encapsulated in a layer of skin-safe silicone in vibrant colors. The team employs silicone overmolding in production and to encapsulate internal hardware for customer beta prototypes.

Dame Products engineers can prototype dozens of overmolded devices in one day by rotating through three or four SLA printed molds. While the silicone rubber of one prototype is curing, the next can be de-molded and prepared for the next fill; finishing and cleaning of de-molded prototypes happens in parallel.

When prototype hardware is returned to the company, the beta device is bleached, the thin silicone layer removed, and the internal hardware is reused in a new beta prototype.

RECOMMENDED MATERIALS AND EQUIPMENT:

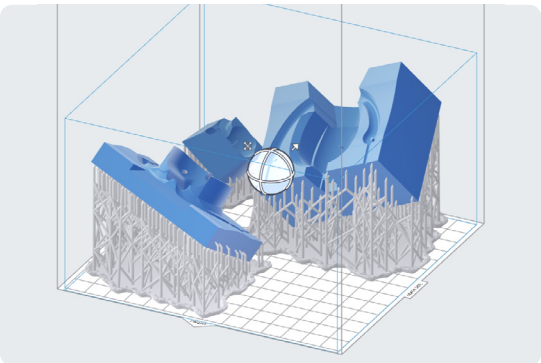
- Formlabs Clear Resin
- Formlabs spatula and flush cutters (provided in Finish Kit)
- Two part medical grade RTV liquid silicone: durometer 20-40 Shore A recommended.
- Syringes
- Epoxy cartridges
- Epoxy gun
- Mixing nozzle
- Stirring sticks
- C-clamps
- Hardware to be encapsulated

OPTIONAL MATERIALS AND EQUIPMENT:

- Silicone dye (optional)
- Petroleum Jelly (optional)
- Vibration source (optional)
- Duct tape (optional)

STEP-BY-STEP METHOD

1. **Print multipart mold in Formlabs Clear Resin:** Printing with 50 µm layer height is recommended. Orient parts so critical interior surfaces are free of support marks.



2. **Wash and Cure the mold, and remove supports:** Wash thoroughly with IPA until the parts have a non-tacky finish. We recommend curing at 60˚C for 15 minutes for Clear Resin. It is helpful to polish the exterior of the mold to a highly transparent finish.

3. **At least one hour in advance: Prepare silicone:** Fill each side of the epoxy cartridge system with one part (A or B), using separate syringes to transfer the liquids. Stand upright and allow silicone to gently degas for at least one hour, or up to one day. An optional step here is to add dye to either the A or B side of the cartridge and mix thoroughly.

4. **Apply Mold Release (optional):** Apply a very light layer of petroleum jelly to the internal surfaces of the mold with a small paint brush. This silicone overmolding technique also works without mold release.

5. **Orient internal hardware:** The alignment pins on the mold aid the positioning of the hardware.

6. **Close the mold, and compress it by hand:** Check the placement and alignment of the hardware through the exterior of the mold. If the hardware appears out of alignment, repeat steps five and six.

7. **Clamp the mold:** Start by clamping in the "direction of draw" or perpendicular to the main parting line of the mold. It's a good idea to check alignment again, since clamping may shift the internal hardware. As an optional step, the Dame Products team has found that sealing the edges with duct tape prior to clamping helps reduce any material seepage and flashing that occurs in RTV mold making.

8. **Assemble the epoxy gun:** Insert the cartridges into the gun and screw on the mixing nozzle. It's helpful to squeeze a little bit of liquid out of the nozzle tip at this stage to make sure you are getting proper mixing.

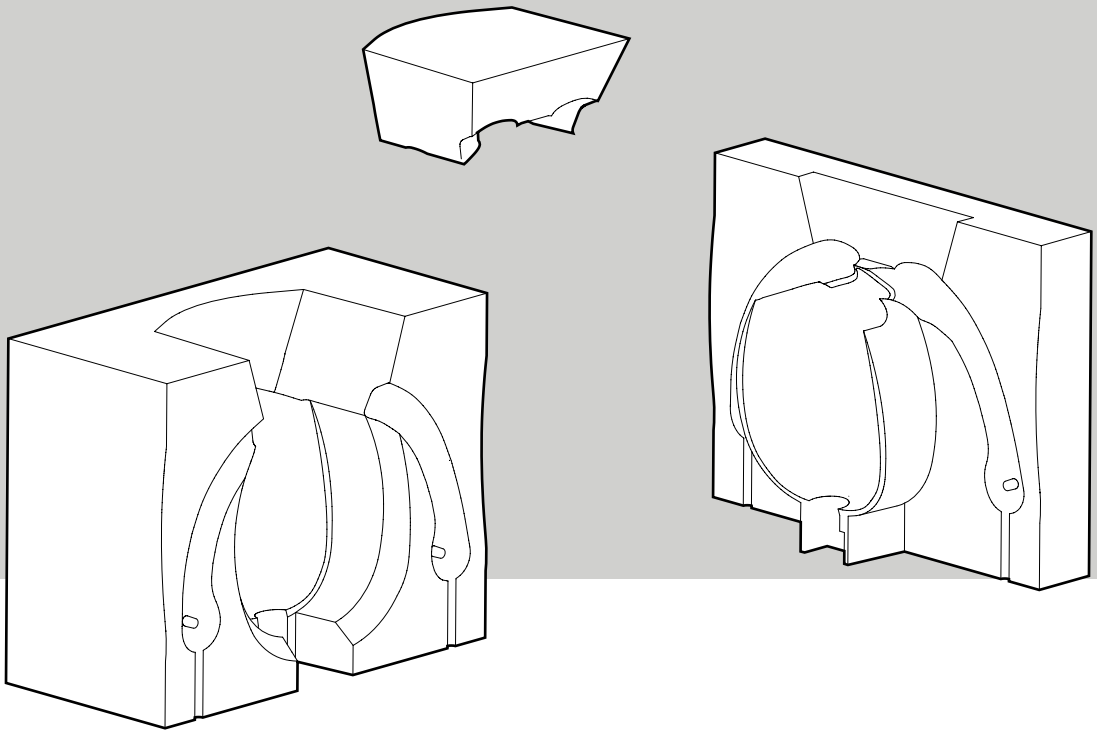
9. **Inject silicone into the mold:** Insert the tip of the mixing nozzle into the mold opening and squeeze the trigger gently. Watch the silicone flow through the mold, and continue to pump until the mold is full and silicone is coming out of all of the vent holes. If silicone continues to sink into the mold after you've stopped, that's because air bubbles are settling or material is seeping at the parting lines. You may need to add a little more a few times after initial fill. After filling, holding a vibrating device (such as a handheld sander) to the surface of the mold can encourage evacuation of air bubbles.

10. **Wait ten minutes:** The silicone that Dame Products uses takes about 10 minutes to fully cure, forming the rubber shell. Check your silicone instructions for recommended curing time. This is a great time to work on trimming

11. **Demold the prototype:** Cut all excess silicone off the exterior of the mold first. Then pry apart the mold with the Formlabs spatula or a flat head screwdriver. Be mindful of thin strings of silicone that form in the mold air vents. Take your time to trim these separately so they do not stay with the mold and pull the silicone off of your hardware. It can also be helpful to trim away some flashing before the object is completely released.

12. **Trim, finish, and clean the prototype:** There will always be flashing to trim off with the Formlabs Flush cutters or a sharp blade. If any air bubbles create voids on the surface, you can paint on additional liquid silicone patches and allow them to cure. Prototypes should be cleaned using industry-specific guidelines before they are handled by beta testers.

13. **Prepare mold for the next casting:** The mold can be re-used multiple times, but you may need to clean out air vents using a sharp object such as a paper clip or drill bit. Return to Step four above.



BEST PRACTICES

a. **Resin selection:** Clear Resin provides a visual queue for mold filling and internal hardware alignment. We recommend printing with a 50 µm layer height for a good balance between smooth surface texture and fast printing time. Orient your parts on the build plate so that interior mold surfaces are free of support marks.

b. **Mold preparation:** Residual resin can interfere with the silicone casting chemistry. Thoroughly washing the mold with IPA ensures that the very first cast comes out well. The outlined process works without mold release, however a thin lining of petroleum jelly can aid the demolding process. We caution that if mold release is too thick, it can interfere with casting chemistry or affect the surface finish of the casted part.

c. **Silicone preparation:** For this application, an epoxy gun is used to inject silicone into the mold; mixing of parts A and B occurs inside the mixing nozzle. To fill, empty epoxy cartridges are set out vertically (Dame 3D printed a holder!) then syringes are used to transfer the silicone A & B from larger containers to the epoxy cartridges. For silicone degassing, the Dame team moves it to cartridges and allows it rest for a day rather than actively degassing in a vacuum chamber. If you also add silicone dye to either part A or B at that time, you can achieve brightly colored silicone rubber.

d. **Alignment pins:** The small bumps shown in the mold schematic are alignment pins used to orient and constrain the part and to set the thickness of the silicone shell. Dame Products engineers typically use a pin diameter of 0.2 mm. Try to have all alignment pins pointing in the “direction of draw” or perpendicular to the main parting line of the mold. The farther that the pin angle skews from this position, the more likely they are to break off and make it difficult to open mold.
When defining the silicone layer thickness, try to aim for 1.5 mm at a minimum. Designing for a 2 mm minimum thickness tends to be more reliable, and 1 mm may work in small areas of the coating. Note that alignment pins do tend to leave small holes in the surface. If needed, these can be patched using a small dab of liquid silicone and allowing it to cure.

e. **Air vents:** Air is displaced when filling silicone into an enclosed space, so air vent channels are incorporated into molds as narrow outlets. It is natural to place a vent at the point of the mold that is last to fill, however the Dame team shared additional best practices for vent placement.
   When designing the mold, it can be helpful to think about areas where air is likely to be trapped, and connect vents specifically to these points. Even when pressure is applied, air bubbles can form around sharp turns, corners, or areas where two flow fronts connect. Bubbles will result in voids in the finished cast part.
   Air channels can be designed to lie along a parting face of the mold or can be embedded in the mold (see diagram above). Avoid placing a channel that bores through two or more parts of the mold. If long air vents are required, they can have a smaller diameter at the base (against the casted part) and a larger diameter at their outlet.
   A note about iterating on your 3D models: If you're always getting an air bubble in the same place, add another air vent to that spot in the mold.
f. **Mold filling:** Dame Products uses an epoxy gun and cartridges, and designs the mold inlet to match the mixing nozzle.
   For complex shapes, the fill direction is quite important. You should try to fill from the highest point of the object, and consider the flow fronts that develop. In the example shown - the product Eva II from Dame - we are dealing with a branching geometry. The best filling method is to start at the high point of the object's main body. and the narrow branching arms are the last regions to fill. Wait until silicone is coming out of all air vents before you stop filling. If one area is filling too fast, you can block it with a finger until the rest of the mold fills.
g. **Trimming, finishing, and cleaning:** An area to consider carefully during demolding is the silicone trapped in air vents. Take care to not yank the mold open as the air vent connection points are areas where the rubbery surface can tear. Often you can do some flash trimming while the part is half demolded, cutting with a sharp blade against the mold itself.

PREPARING FOR MANUFACTURING

The Dame Products team highlights two main differences between the 3D printed prototype mold and the molds used in product manufacturing. First, the production mold is made from machined metal. Second, the alignment pins are often oriented within the plane of the mold's main parting line, and are designed to retract in and out of the mold. This results in an overmolded layer that does not have dimples and holes created by the alignment pins.

Conclusions

Hybrid techniques such as silicone casting are expanding the material palette of 3D printing using highly accessible materials and equipment. The methods outlined in this paper can be used directly, or elements of each borrowed for custom applications.

Variations of these methods are described below:

1. If you are replicating parts with structural or surface details on all sides, you can expand on the “ice tray” method to create a two-part mold from silicone. Our RTV mold making white paper for jewelry provides a good overview of this technique.
2. If you are prototyping a grip or handle, a partial overmold can be created on a part. Because the part is not completely encapsulated, you may need to add some features to the target geometry that lock the silicone layer into place. This could be achieved using liquid or putty type silicone.
3. For creating objects with small, fine details, investment casting with wax can be used. Formlabs created a free video webinar to show how this is done in the jewelry market.

Still have questions about using an SLA printer to create silicone molds? Reach out to our solutions specialist to be put in touch with a Formlabs expert who can answer your questions.

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