Ceramic Resin is the first Form X experimental material from Formlabs. If you’re looking to explore materiality with your Form 2 and create prototypes for product design, engineering, medical applications, and beyond, this material is for you. Ceramic has a distinctive aesthetic straight out of the printer, and it can also be fired to produce a fully ceramic part, allowing ceramicists to experiment with more complex geometries and explore how traditional techniques translate to this modern fabrication process. Below, we provide guidelines that have proven successful during our testing process. Developing a specific firing and glazing process is up to you.
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Data</td>
<td>3</td>
</tr>
<tr>
<td>Firing Schedule</td>
<td>4</td>
</tr>
<tr>
<td>Printing with Ceramic Resin</td>
<td>5</td>
</tr>
<tr>
<td>Firing</td>
<td>7</td>
</tr>
<tr>
<td>Design Guidelines for Fired Parts</td>
<td>8</td>
</tr>
</tbody>
</table>
# Mechanical Data

<table>
<thead>
<tr>
<th></th>
<th>Metric</th>
<th>Imperial</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green¹</td>
<td>Post-Cured²</td>
<td>Green¹</td>
</tr>
<tr>
<td>Tensile Properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile Strength at Yield</td>
<td>12.1 MPa</td>
<td>15.9 MPa</td>
<td>1760 psi</td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>3.9 GPa</td>
<td>5.2 GPa</td>
<td>568 ksi</td>
</tr>
<tr>
<td>Elongation at Failure</td>
<td>1.0 %</td>
<td>0.94 %</td>
<td>1.0 %</td>
</tr>
<tr>
<td>Flexural Properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>2.5 GPa</td>
<td>3.5 GPa</td>
<td>363 ksi</td>
</tr>
<tr>
<td>Impact Properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notched IZOD</td>
<td>14.4 J/m</td>
<td>14.5 J/m</td>
<td>0.270 ft-lbf/in</td>
</tr>
<tr>
<td>Temperature Properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat deflection temp. @ 66 psi</td>
<td>290 °C</td>
<td>290 °C</td>
<td>554 °F</td>
</tr>
<tr>
<td>Heat Deflection Temp. @ 264 psi</td>
<td>60.3 °C</td>
<td>104 °C</td>
<td>140.5 °F</td>
</tr>
</tbody>
</table>

**NOTES:**

¹Data was obtained from green parts, printed using Form 2, 100 μm, Ceramic settings, without additional treatments.
²Data refers to post-cured properties obtained after exposing green parts to 2.5 mW/cm² of 405 nm light at 60 °C for 1 hour.

Ceramic Resin is actively under development, these properties reflect the current formulation and may be subject to change.
Firing Schedule

The firing process for Ceramic has two main phases: burnout and sintering. Burnout occurs between 280 °C and 460 °C at a slow rate to allow gases to escape. The material is fragile between burnout and sintering, so a fast ramp to the sintering phase lowers slump. Finally, the sintering phase causes the outer boundary of the ceramic microparticles to merge together forming a structural product.

Important Steps for Successful Firing:

- Ensure printed parts are fully dried and post-cured.
- Ceramic Resin requires a slow ramp rate during Stage 3 to achieve a consistent polymer burnout. Ramping too quickly will cause cracking and bubbles.
- Allow parts to cool completely in the furnace before removing them.
- Ensure the kiln cools down slowly after reaching the maximum firing temperature. Allow parts to cool completely in the furnace before removing them.
1. Printing with Ceramic Resin

Apply adhesive-backed polyester film to a clean, dry build platform before printing. Large prints and rafts will adhere very strongly to the build platform, and this technique ensures you can successfully remove parts. Always print on supports, and use the large default touch points suggested in PreForm. Because Ceramic supports are brittle, they’ll be easy to remove later.

**TIP:** If you plan to fire parts, consider scaling your part by at least 13% to compensate for shrinkage. Actual shrinkage varies by part geometry, but is typically between 13-21%.

**WARNING:** Ceramic Resin is particularly difficult to clean off of the printer’s acrylic cover in the event of a spill. Spills may occur if a part falls from the build platform support tips and the printer continues operation. Start with smaller or lighter prints, generously apply supports with larger touchpoints, and, if possible, keep an eye on your print so that you can cancel early if issues occur.

Shake the cartridge before use. If a resin tank has been sitting unused, mix the resin by moving the wiper back and forth.
Remove parts from the film using the normal tools and procedures. The same film can be reused for future prints. If the film starts to pull away from the build platform or is damaged during part removal, replace it.

Remove supports by breaking them off the part with your fingers or flush cutters. After washing, let the part air dry, then sand support marks with 400 grit sandpaper to remove them.

**TIP:** If you plan to glaze parts, follow the IPA wash with a soap and water rinse to remove additional ceramic particles from the surface. Be sure your part is completely dry before firing.

Post-curing improves the mechanical properties of Ceramic prints and is vital prior to firing. This ensures that the photopolymer matrix is completely reacted, which reduces cracking during firing. Post-cure parts at 60 ºC for at least 60 minutes under a 405 nm light source.
2. Firing

Firing turns the printed photopolymer into a fully ceramic product. As the polymer burns off, the material becomes porous, leaving room for the ceramic microparticles to sinter together. In the fired state, Ceramic is resistant to temperatures up to 1000 ºC.

**WARNING:** The Burnout phase creates fumes that require adequate kiln ventilation. If ventilation affects the internal temperature, ventilation fan speed can be reduced above 400 °C to help reach the higher temperatures required for Sintering.

Use an electric kiln or furnace with programmable temperature control with the recommended firing schedule. Expect shrinkage of 13-21% and some slump deformation during this stage. For more information on non-uniform geometric variance caused by firing, see the Design Guidelines.

Parts can be glazed using traditional methods. Follow the glaze manufacturer’s recommended firing process for best results.

**TIP:** Apply glaze in thin layers for full coverage. An overly thick glaze layer will crawl or blister.
Design Guide for Fired Parts

This Design Guide will discuss some of the shrinkage and other geometric deformation that occurs during firing so that you can account for these changes in the design of your 3D model. We’ll also outline some of the minimum features that you might expect to survive when firing parts.

**SHRINKAGE**

Shrinkage is unavoidable during firing, and complicated to design for, since it relates to the specific geometry of your part. Smaller, thin-walled parts will shrink less than large, thick-walled parts. If you have a particular final geometry in mind and you plan to fire parts, we suggest scaling your model up by at least 13%.

**GENERAL SHRINKAGE**

Recommended: 17% ±4%

Actual shrinkage varies by part geometry, but is typically between 13-21%. General shrinkage can be compensated for by scaling your part accordingly in PreForm prior to printing.

**VERTICAL SHRINKAGE**

Recommended: +3%

Parts will compact along their vertical axis in the kiln. You can compensate for this in your CAD model, but you may need to experiment with different amounts of scaling in the Z dimension.

**VARIABLE SHRINKAGE**

Recommended: ±5%

Shrinkage is not always even and predictable. Regions of a model tend to shrink more when they’re longer or thicker than other parts of your print. To compensate for variable shrinkage, you may want to perform a test firing, then compensate for non-uniform deviations in your CAD model, reprint, and fire again.
SAGGING
Parts may slump or bend outward during firing after the polymer burnout. To help compensate for this, print additional support into your model, or consider internal or external strategies to help support models in the kiln.

RIBS AND SPARSE INFILL
Ribs can help parts resist sagging. Thicker walls tend to shrink more than thinner sections. Improve stability without changing the surface of a model by creating hollow walls with interior ribs.

CUSTOM SETTER
You can prefabricate a setter to support parts during firing. Create a setter by offsetting the internal surface of hollowed regions by 0.5 mm. This is especially effective with cup-like geometries, where the interior of the cup can rest against a negative form.

CRACKING
Cracking is a very common issue. The widest point of the crack tends to indicate where the crack started, and the direction of the crack lets you see possible underlying stresses in the clay.

FILLETING CORNERS
Recommended fillet diameter: 3.0 mm
Cracks start at sharp interior corners. Adding fillets or smoothing helps strengthen corners and reduce cracking. Sharp outer edges can benefit a part’s stability.
MINIMUM FEATURES
There are different limitations for fine parts you can successfully fire compared to parts you simply intend to use in their green printed state. If you plan to use parts in an unfired state, you do not need to compensate for shrinkage, and can refer to the general Formlabs Design Guide.

MINIMUM SUPPORTED WALL THICKNESS
Recommended: 1.00 mm
A supported wall is connected to other walls on two or more sides. Supported walls thinner than 1.00 mm may slump or break during the firing process.

MINIMUM UNSUPPORTED WALL THICKNESS
Recommended: 1.25 mm
An unsupported wall is only attached to the model on one side. Short unsupported walls should be at least 1.25 mm thick. Short walls are wider than they are tall. Tall models that are thinner and lighter at the top and thicker at the bottom tend to be more stable.

MINIMUM ENGRAVED DETAIL
Recommended: 1.5 mm
Engraved details are recessed features on your model. Recessed details smaller than 1.5 mm may merge or become indistinct after firing.

LATTICE THICKNESS
Recommended strut thickness: 1 mm
Lattices benefit from having thicker struts at the base than at the top of the structure. Lattices can also be used to create a sparse infill that helps reduce shrinkage.
Interested in Ceramic?

Ceramic Resin is under active development, and will be available in early 2017.
Fill out our online form to learn more about using Ceramic.

Inquire About Ceramic