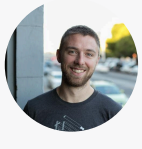
Ultimate Guide to Finishing 3D Printed Parts



Written by Dave Evans

On March 26, 2015 | In Engineering

Executive Summary

In this article we're going to look at different finishing methods for FDM and PolyJet parts and the techniques and tips that can elevate the look and feel of your prototypes.

As a case study, we're going to use a simple Apple Watch stand design, a model with pockets and internal and external features that needs to be surface finished to a standard that does the watch justice!

Our watch stand design is heavily inspired by the DODOcase stand here and the TRIO stand here - Check them out!

Short on time? Here's a quick overview of the main points this article covers:

- **PLA:** If you're working with a tight budget then PLA is going to be your best material choice; the results aren't as polished but the price is cheapest.
- **ABS:** If your budget is moderate then go with ABS. It's not as cheap as PLA but

still at a low price point and the material is more reliable than PLA.

- **VeroBlack:** For the highest quality parts go with VeroBlack (or VeroWhite). This will give you the best dimensional accuracy and best overall polished look.

Interested in the specific tips and tricks we used to get the best surface finishing results for each material? Then read on!

A conceptual render of our demonstration piece: a simple stand for an Apple Watch. Thanks to Michael Christensen for the Apple Watch CAD off of GrabCAD!

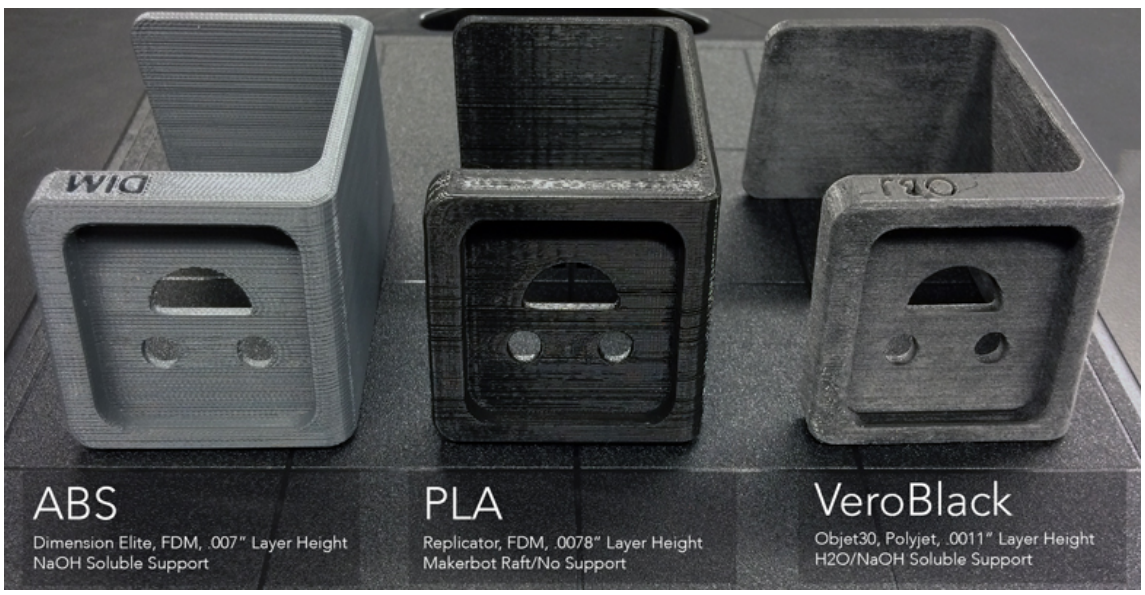
Overview of Materials

The finishing process we'll use on these three parts is going to involve a combination of repairing and preparing the print for post-processing, sanding, and painting.

All three models will be finished to achieve a smooth, matte black surface and each

print comes with unique challenges and considerations to arrive at the best finish possible.

The process for each material is detailed separately and at the end we'll compare the results.



Mat'l (Printer)	**ABS** (Dimension Elite)	**VeroBlack** (Objet30)	**PLA** (Replicator 5th gen.)
Printer Type	FDM	Polyjet	FDM
Support	NaOH Soluble	Water/NaOH Soluble	None/MakerBot Raft
Layer Height	.007"	.0011"	.0078"
Sandability	Easy	Medium	Hard

ABS (Printed on a Dimension Elite)

The Dimension Elite prints are smooth, clean, and ready to sand out of the NaOH bath.

There are, however, clear stepping lines between the printed layers. If we don't remove these stepping lines, they'll show up in the final paint coat which will ruin our smooth finish. Thankfully, removing these will be easy thanks to ABS's high melting point and easy sandability.

Materials Needed

The materials we'll be using:

- Sandpaper (grits 100 to 600)
- Medium, fine, and extra-fine sanding sponges
- XTC-3D brush-on coating (As an alternative, Bondo putty is a common solution to fill holes in parts. We chose XTC-3D for its viscosity, sandability, and ability to penetrate small perforations, which makes it desirable over Bondo putty)
- Razor blade
- Foam brush, mixing cups and popsicle sticks
- Sandable Krylon Primer
- Montana Acrylic Primer in Shock Black
- Matte Acrylic Varnish

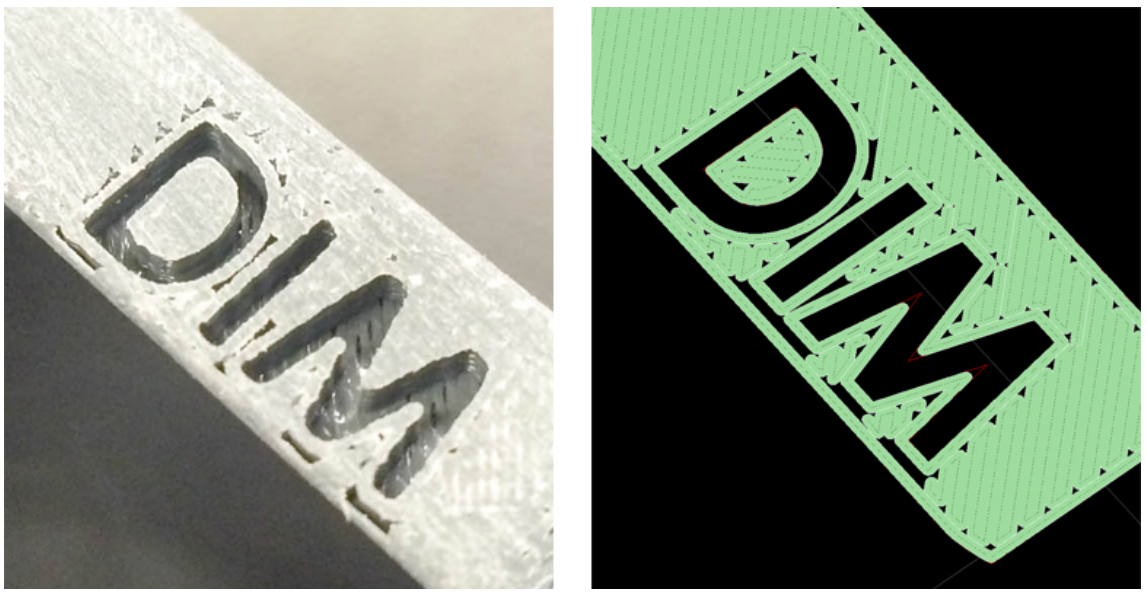
Sanding

Sanding the ABS print is simple and straightforward. First start with 100 - 200 grit sandpaper to remove stepping lines and then gradually increase up to 600 grit to achieve a smooth finish without sanding lines.

Pro Tip: Sand in small circular movements evenly across the surface of the part. Avoid sanding in one direction only, especially in the direction of the stepping lines to prevent striations or “trenches” in the print.

Beware that ABS is very easy to sand, so be careful not to overdo it. Removing as little as .010” can be enough to completely remove any stepping layers and oversanding can compromise critical dimensions.

After sanding the parts, some holes are revealed on our part left by an incomplete layer around the letters DIM. These holes can perforate through the finished paint coat to create ugly sinkholes, so we need to find a solution.



Sanding reveals the holes left by the incomplete layer and are represented in Catalyst, where black shows lacking toolpaths in the top layer.

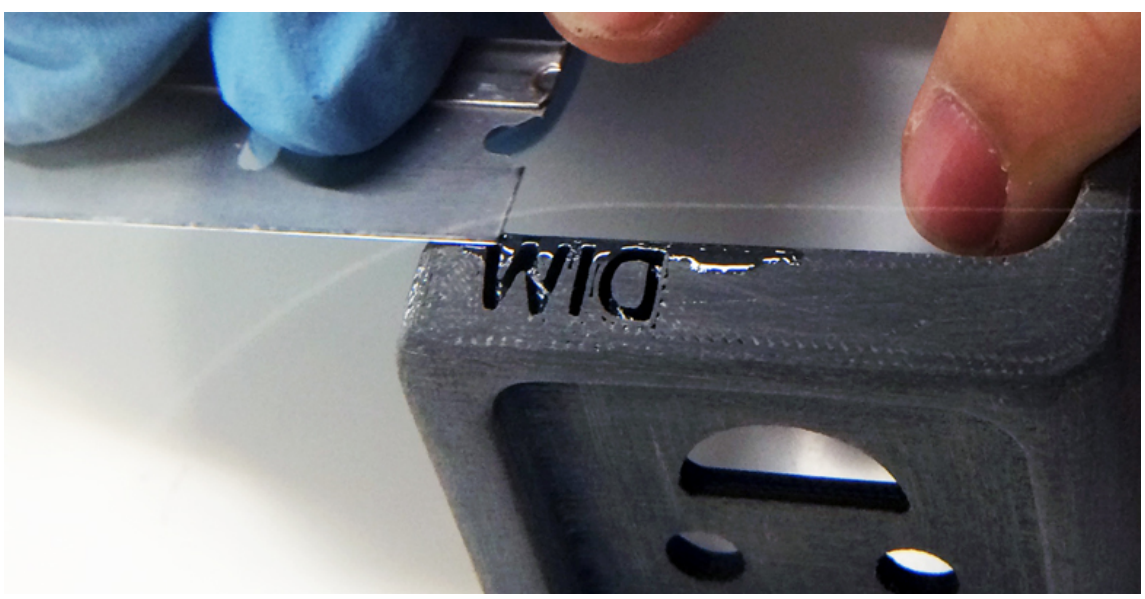
As you can see in the Catalyst tray to the right, there are large holes between the DIM and the edge of the part. Moving the DIM up in our Solidworks model would solve this, but for now we'll have to find a way to fill these holes with a sandable filler.

Repairing the Incomplete Layer

We're going to use a thin, sandable epoxy called XTC-3D to fill the tiny holes and crevices in our print. XTC-3D is cheap (a 24 oz bottle costs about $25), quick, thin, and effective. Note that a small amount goes a long way (within the 10 minute pot life).

Pro Tip: Be sure to maintain a weight ratio of 100 Part A to 42 Part B. Mix thoroughly for one minute and coat your part within the 10 minute pot life. For more details, check Smooth-On's technical bulletin here, and a great instructional example here.

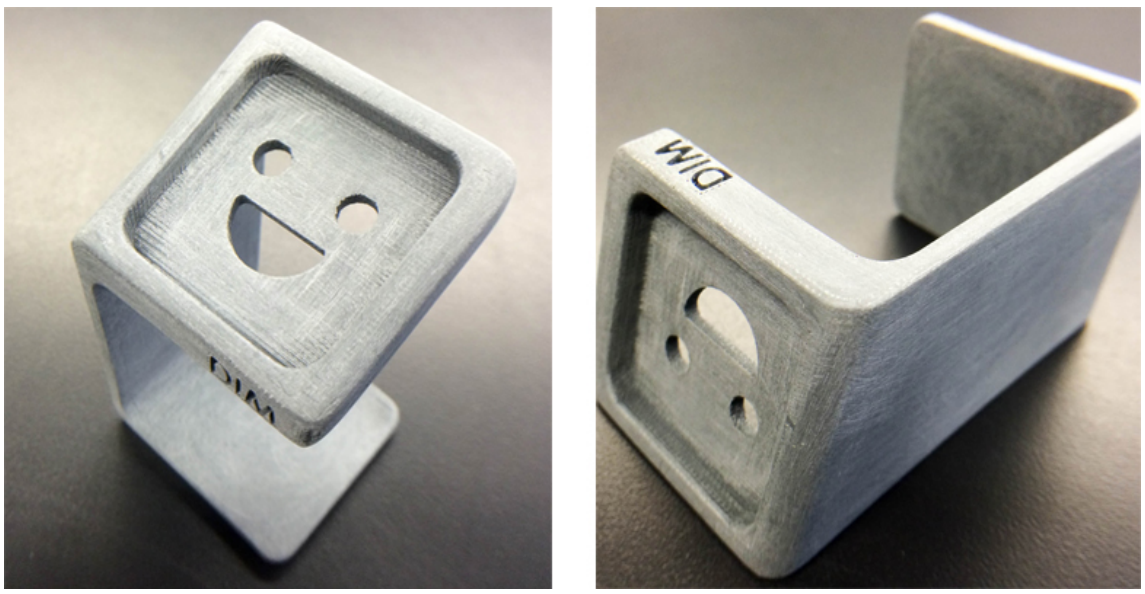
Before applying the XTC-3D, wash the part with soap and dry with compressed air to ensure your part is thoroughly clean and free of any oils or sanding dust. Also make sure to wear gloves so as not to get any hand oils or sweat on your part.



Preparing the XTC-3D to fill the holes in the Dimension parts. A small amount of XTC-3D goes a long way: 12 grams was more than enough to repair the holes in the Dimension print and completely cover another PLA model.

Fill in holes or gaps in your print with a very thin (1/64”) coat; a thin layer of XTC-3D will level itself out. We used a razor blade to scrape excess XTC-3D into the unwanted holes and gaps, making sure to avoid any areas we didn’t want filled (like the letters DIM).

Allow the XTC-3D sufficient time to become tack-free dry (approximately 2 hours). Now we’re ready to continue sanding away at the excess XTC-3D layer with 300 to 600 grit to reveal the repaired surface.



A sanded and repaired ABS print. Note that the some layers are still apparent on difficult-to-sand internal corners.

Then, after another thorough wash, we're ready to begin preparing our repaired surfaces for painting.

Priming and Painting

Painting 3D printed parts is a vast world of acrylics, enamels, sprays, and airbrushes.

In this example, we'll be using Montana spray can paints to follow a relatively straight forward process: prime, dry, paint, dry, varnish, dry.

Standard spray painting principles apply:

1. First make sure your surface is oil-free, dust-free and hole-free
2. Shake your cans for at least two minutes prior to painting
3. Ensure your cap is clean to prevent drips

4. Be aware of how the paint is accumulating on the part and look for any pooling or dripping
5. Paint in many light coats rather than fewer heavy coats; this is especially important for 3D printed parts with internal and obscured geometries
6. Paint in controlled, well-ventilated and well-lit areas

The Dimension prints started with very obvious stepping between layers. If you've sanded properly up until now to create as smooth a surface as possible, these layers shouldn't show up in your final paint finish.

The Final Result

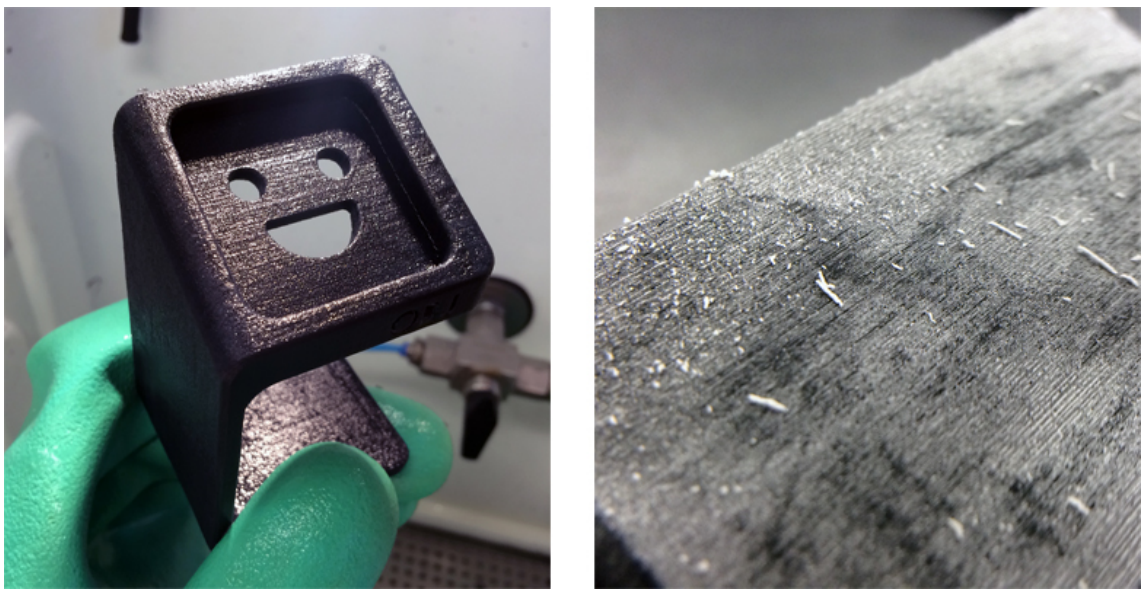
The finished ABS part. Notice stepping is still visible on sharp internal geometry at Circle 1. but the holes around the DIM are not visible in the paint coat at Circle 2.

The finished ABS part is matte black and smooth to the touch with very little evidence of layering in most surfaces. A few important results to note here:

- Sharp internal pockets are tough to sand. After about 30 minutes of sanding, we still had a hard time removing all the layering and the stepping shows up even after priming, painting, and varnishing the print.
- Because we had to remove more surfaces from the sanding, there is some sacrifice in regards to the final geometry of the part.
- Filling the incomplete layer with a thin coat of XTC-3D worked very well; those holes are invisible in the final paint layer.

VeroBlack (Printed on an Objet30)

Thanks to .0011" resolution, the Objet30 prints have some stepping between layers, but nowhere near as obvious as in our FDM prints.



Left: *freshly cleaned VeroBlack part out of bath after support material removal.* ***Right:*** *After drying there will still be trace amounts of residue which will fall off in small soft white chunks with dry sanding at around 100 to 300 grit.*

The Objet30 prints come out of the printer with a thick layer of support material so before we can begin finishing our VeroBlack part, we'll need to remove this support and the residue it leaves behind.

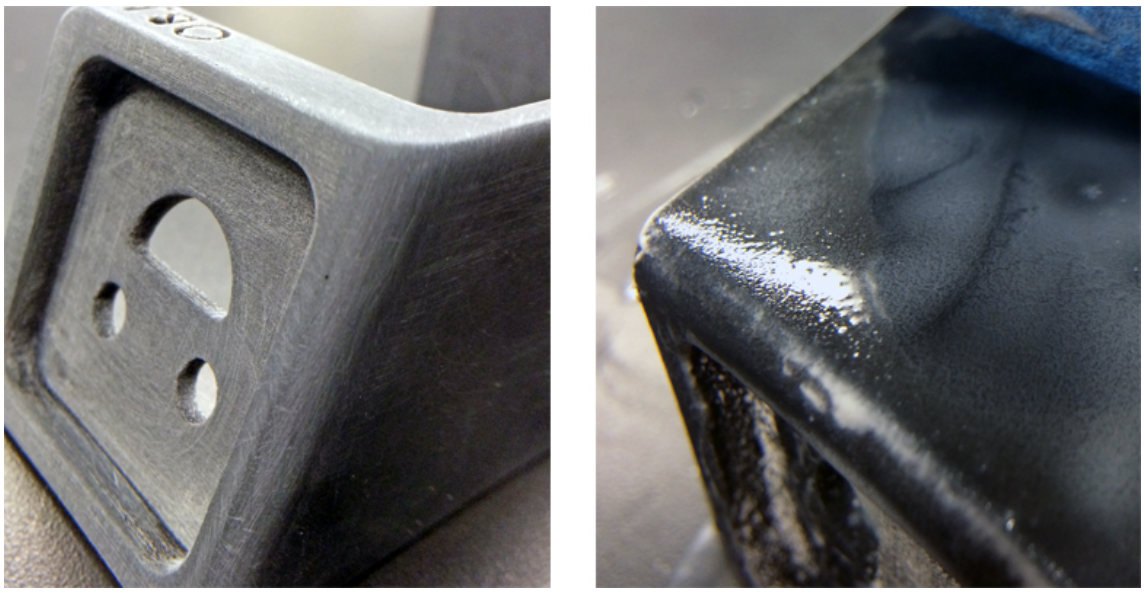
Materials Needed

The materials we'll be using:

1. Sandpaper (grits 100 to 600)
2. Medium, fine, and Extra fine Sanding Sponges
3. Sandable Krylon Primer
4. Montana Acrylic Primer in Shock Black
5. Matte Acrylic Varnish

Sanding

Start with 100 grit sandpaper to remove the residue and gradually move to 300 grit; the residue will fall off in small soft white chunks. This is the hardest part of the VeroBlack finishing process and it took us about 30 to 40 minutes to remove all of the residual layer.



Left: *Removing the residue will reveal a harder surface that we can paint on.* ***Right:*** *Wet sanding through 600 grit to remove the residual layer is very effective, thanks to the Objet's water soluble support material.*

After removing the residual layer by wet sanding through 300 grit sandpaper, the surface of the part will begin to feel smooth. If you rub the part with your fingernail, you'll feel it's harder and more like plastic beneath the gummy residual coat. Continue sanding through to 600 grit until the part is fully smooth.

Pro Tip: Water breaks up the residue, so wet sanding is a highly effective method to get a smooth, residue-free and paintable surface.

Next, even though you've been wet sanding this entire time, make sure to thoroughly clean your part with soap and water before you move on to the next step. Again, we recommend using compressed air to dry the part and clear any accumulated dust.

Beware that VeroBlack is like ABS: very easy to sand, so be careful not to overdo it. Once you break through the residual layer, the actual VeroBlack will sand very easily.

Removing as little as .005" can be enough to completely remove any stepping layers and oversanding can compromise critical dimensions.

Priming and Painting

Next we're going to paint the VeroBlack part just as we did the ABS part: using Montana spray can paints with the following process: prime, dry, paint, dry, varnish, dry.

Once again, standard spray painting principles apply:

1. First make sure your surface is oil-free, dust-free and hole-free
2. Shake your cans for at least two minutes prior to painting
3. Ensure your cap is clean to prevent drips
4. Be aware of how the paint is accumulating on the part and look for any pooling or dripping
5. Paint in many light coats rather than fewer heavy coats; this is especially important for 3D printed parts with internal and obscured geometries
6. Paint in controlled, well-ventilated and well-lit areas

Final Results

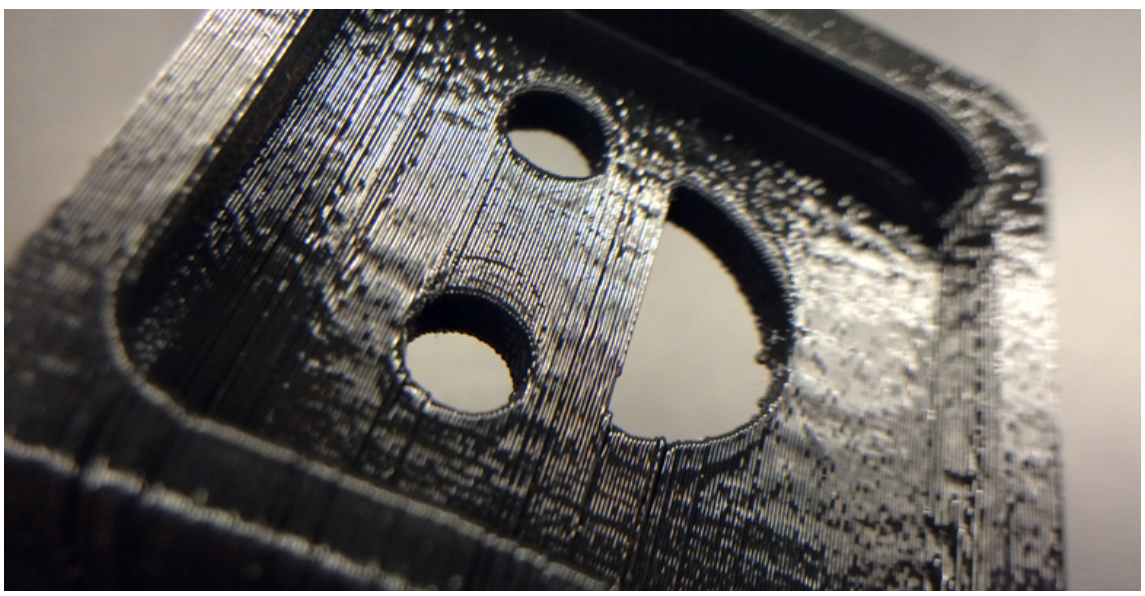
A finished VeroBlack part. ***Circle 1:*** *Notice how areas where the residue was not properly removed have a powdery paint finish.* ***Circle 2:*** *Faint stepping is visible in the paint finish, but for the most part starting with a smooth part has resulted in a smooth paint finish.*

The finished VeroBlack part is matte black and smooth to the touch. A couple points to note here:

- Some of the internal corners were not sanded enough to remove the residue, so you can see how the paint powdered up in these areas.
- Although very little stepping is visible on the part, you can see slight evidence of it here. This part could have probably used 30 more minutes of thorough sanding.

PLA (Printed on a 5th gen. Replicator)

Now for the dreaded PLA, a notoriously difficult material to finish. But with some tricks and patience, it too can join ABS and VeroBlack in the ranks of matte black glory!



A PLA print from a 5th generation Replicator. Notice the severe stepping between layers and the unevenness of layers in the plane of the print.

This particular Replicator print came off the plate with severe striations: see the parallel grooves in the layers of the part above. This could be a result of machine quality, but for now we'll just have to find a way to maneuver these striations to a smooth part.

Sanding PLA is difficult in part because of how soft and gummy it becomes if you try to sand too aggressively or quickly, so we'll explore options on how to smooth this material with minimal effort and abrasion.

Sanding

If you choose to sand the PLA directly, the process is very straightforward. PLA is not as forgiving as ABS when it comes to sanding and abrasion, so you will likely spend more time removing the stepping between layers, especially with the severe striations in a print like ours.

Begin with a low (100 - 200) grit, sanding away at the bumpy striations and any raft or support material left behind. Particularly in the case of MakerBot support, it's easiest to remove them with a plier first before sanding away them.

Depending on the size and geometry of your part, you'll likely be stuck in the 100 - 300 grit range for a while to smooth out striations and pesky support remnants.

Once layering and striations are less prevalent, move through higher grits (400 - 600) to achieve a surface ready for priming and painting.

Pro Tip: Patience is key when sanding PLA. Turn on a movie or your favorite show, but don't zone out! Sand in small circles evenly across the surface of the part.

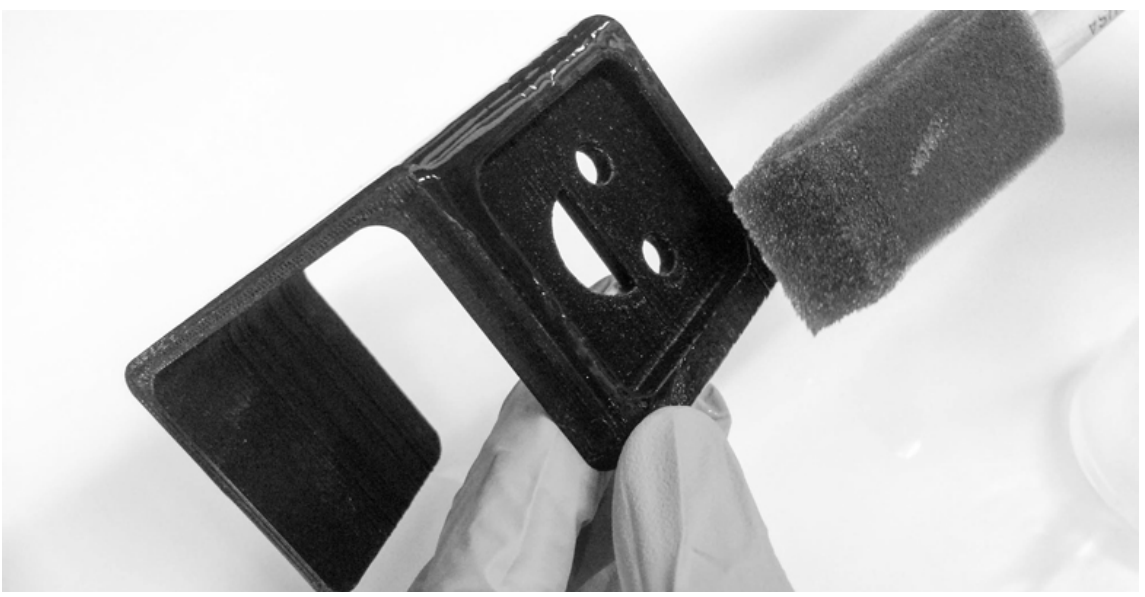
An alternative method to sanding PLA directly is to finish the PLA with the XTC-3D first and then sand on top of the coating.

Finishing

We're going to use XTC-3D to create a smooth, sandable, paintable layer of epoxy around our PLA print.

Before applying XTC-3D, ensure that your part is thoroughly clean, free of any oils and sanding dust (sensing a pattern yet?). Wash the part with soap and dry with

compressed air to clear any dust. Again make sure to wear gloves to protect both your part and your hands.



Applying a thin (1/64”) coat of XTC-3D. Watch out for areas where XTC-3D may pool up, such as internal pockets.

Brush on the XTC-3D in a thin (1/64”) coat; as long as the coat is thin enough, it will level itself out. Between coats, leave 1.5 hours for the XTC-3D to dry.

It may be difficult to coat an entire part at once, so don’t be afraid to do it in sections, making sure to keep overlapping to a minimum between sections. Wait 90 minutes between coats and after you’ve finished wait 2 hours to allow the surface to become tack-free.

With striations as severe as ours, it will take multiple coats to get a smooth surface, so patience is key. Remember that multiple thin coats will level better than thick coats.

Pro Tip: Internal pockets are susceptible to pooling so be careful to suck up or

remove any pooling that occurs before the XTC-3D begins to dry (that's what we're doing in the left picture above).

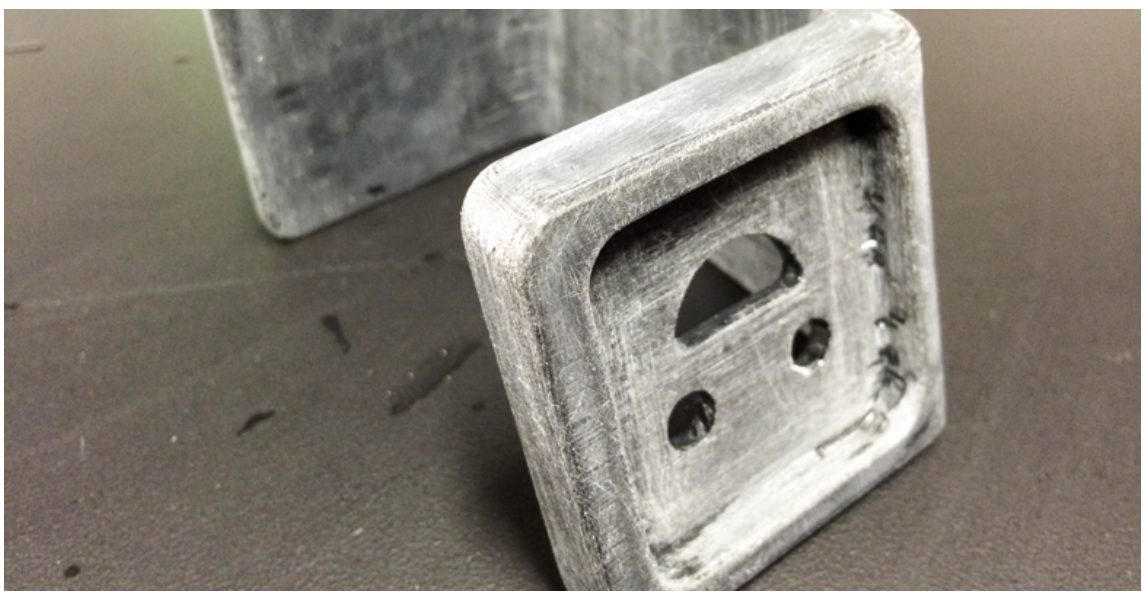
Beware that XTC-3D may compromise critical dimensions, but applying thin coats will allow you to minimize the additional material.

Left: *A thin coat of XTC-3D. Notice how striations are still visible in the reflection of the part. Multiple coats may be needed to achieve a flat surface.* ***Right:*** *Apply thin coats to avoid pooling in internal pockets.*

After the XTC-3D layer has hardened (two hours after application of the last coat) it should be ready for sanding. Follow basic sanding guidelines, starting with 300 grit (thanks to the smoothness of the XTC-3D) and sanding in small circular movements to even the surface. Any wavy patterns may require a coarser grit to remove.

The sandpaper will scratch up the XTC-3D coat; focus on getting a level surface, moving through to 600 grit.

After you've finished sanding, make sure to thoroughly clean your part with soap and water and then dry using compressed air before moving on to the next step.



Sanded and cleaned PLA part that has been coated with XTC-3D. Notice how the internal pockets have pooling and are also poorly sanded.

Priming and Painting

Painting the PLA part goes by the same process as the ABS and VeroBlack parts: prime, dry, paint, dry, varnish, dry.

Standard spray painting principles apply:

1. Make sure your surface is oil-free, dust-free and hole-free
2. Shake your cans for at least two minutes prior to painting
3. Ensure your cap is clean to prevent drips
4. Be aware of how the paint is accumulating on the part and look for any pooling or dripping

5. Paint in many light coats rather than fewer heavy coats; this is especially important for 3D printed parts with internal and obscured geometries
6. Paint in controlled, well-ventilated and well-lit areas

Final Results

A finished XTC-3D coated PLA part. ***Circle 1:*** *Pooling of the XTC-3D has shown through the paint finish.* ***Circles 2 & 3:*** *Striations are still visible on the part.*

The XTC-3D coated PLA part is matte, black, and smooth to the touch with a few problems:

- Although the XTC-3D has worked well to smooth the part and make sanding quicker and easier, it has left pooling in the internal pocket that has shown through the paint finish.
- Striations are still visible on the part. 30 more minutes of sanding could have prevented these from showing through the final paint finish.

Results and Closing Thoughts

After finishing all three parts to a smooth, matte black finish, let's take a look at the differences in process, time, materials and finish.

Mat'l (Printer)	**ABS** (Dimension Elite)	**PLA** (Replicator 5th gen.)	**VeroBlack** (Objet30)
Printer Type	FDM	FDM	Polyjet
Support	NaOH Soluble	None/MakerBot Raft	Water/NaOH Soluble
Layer Height	.007"	.0078"	.0011"
Hours Required to Finish (Not counting XTC-3D cure time)	2 hours	3 hours	1.5 hours

Differences in Process

ABS (Dimension Elite)

- Sand from 100 to 600 grit
- Repair holes with XTC-3D (may not apply to your part)

- Sand away XTC-3D with 300 to 600 grit
- Prime, Paint, Varnish

VeroBlack (Objet30)

- Sand from 100 to 600 grit
- Prime, Paint, Varnish

PLA (Replicator 5th gen.)

- Coat in 1 to 3 layers of XTC-3D (depending on how bad the striations on your print are)
- Sand away XTC-3D with 100 to 600 grit
- Prime, Paint, Varnish

Differences in Time

The part that took the longest to finish was PLA due to the XTC-3D coating time. Even without XTC-3D, however, PLA typically takes longer to sand than ABS or VeroBlack.

In our example, the VeroBlack was ultimately faster to finish since we repaired our ABS print with XTC-3D and stepping between layers was not as significant in the VeroBlack print.

All things considered, VeroBlack was the quickest to get to a smooth, matte black finish.

Pro Tip: If you're in a rush to get from printer to photoshoot, pick the Dimension Elite or Objet30. Especially in models with overhangs and significant amounts of support, the Dimension Elite and Objet30 both have support that is quickly removable via dissolution, whereas the PLA support on a Replicator can significantly increase the time required to get to a smooth part.

Differences in Cost and Materials

It's important to consider the amount of time it will take to finish your model as well as the overall look and dimension when considering price.

PLA is the cheapest out of the three, at $20 per part, followed by ABS at $55, and VeroBlack at $110. In our opinion, VeroBlack is the best bang for your buck since it's the shortest to surface finish and will give you the most accurate model.

Comparison of the Final Results

At first glance, all three models may look very similar, but there are a few key differences in the final finish.

Both the ABS and the PLA print have evidence of stepping between layers that is visible in the final paint coat. The VeroBlack print requires much less effort to remove these steps, which ultimately are not as obvious in the final paint coat.

Although the ABS and the VeroBlack print have very similar surface finishes, more material (approximately .020") was lost in the sanding process for the ABS in order to remove stepping between layers. In contrast, the VeroBlack print required less

sanding so the final dimensions are closer to the original design intent.

Individual Summary of Each Part

VeroBlack: High layer resolution (.0011”) means little sanding is required to get a smooth, paintable part. Critical dimensions don’t need to be compromised to get a smooth part and no repairs are needed for detailed features.

ABS: Parts are easy to sand, but small detailed features may require repairing and careful sanding to remove stepping between layers. Once this stepping is removed, painting is straightforward.

PLA: The cheapest option, but also has potential to be the most difficult to finish, depending on support structures and quality of the print. May require significant sanding and repairing via XTC-3D or Bondo filler.

Dave Evans

Written by

Fictiv Co-founder. I'm a hacker at heart and an engineer who likes to build things (and sometimes take things apart).

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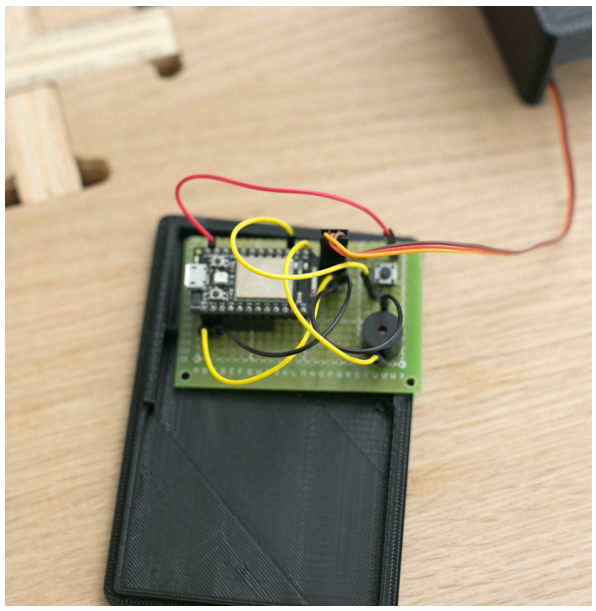

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