An Ebook by

sculpteo
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THE COMPLETE **SURFACE FINISH GUIDE** FOR 3D PRINTING

Additive Manufacturing
at your scale.

CONTENTS

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INTRODUCTION

THE PERCEPTION OF 3D PRINTED PARTS

The three big myths shaping the perception of 3D printing

While 3D printing has been around for decades, the technology remains uncertain to many professionals. Questions of quality, applications, scalability, and cost remain, limiting the way industries capitalize on this technology. Let's look at the three big myths about 3D printing and separate fact from fiction.

Myth 1: 3D printing can't make quality parts

3D printing is so much more than visible layers and stringy failed prints; in fact, 3D printing is more than just FFF (Fused Filament Fabrication) technology. 3D printing comprises more than ten different technologies for polymer, metal, and photopolymer materials.

The last several years have seen massive developments in quality. Industrial 3D printing solutions are now delivering parts comparable to injection molding with smooth surfaces, no visible layers, and professional mechanical properties.

Ultrasint® TPU01 - MJF, Coating finish (Source: Forward AM)

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Myth 2: 3D printing is only for prototyping

It's clear that 3D printing for prototyping presents incredible benefits for product development. But, with the evolution of industrial technologies, 3D printing is now a perfectly adapted solution for series production and end-use parts.

52%

use 3D printing for end-use mechanical parts

27%

use 3D printing for end-use consumer goods

The State of 3D Printing 2021, Sculpteo

Why choose 3D printing for series production? Many companies are able to benefit from mass-customization, limited editions, and on-demand manufacturing to be more responsive to market demands. 3D printing offers competitive costs per part and shorter turn around times for small and medium production runs impossible to achieve with traditional manufacturing methods.

Ultrasint® PA11 - SLS, Unfinished

Myth 3: 3D printing is not industrialized

Along with the demand for quality parts, scalability is also becoming essential for businesses looking to adopt 3D printing. While the common conception of the technology is a simple desktop 3D printer, capable of producing parts one at a time, today, industrial machines are producing thousands of parts in a single batch with powder bed fusion technologies.

These industrial 3D printing technologies allow for scaled production with high-performance materials rivaling injection plastics and even metal parts.

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KEYS TO ACHIEVING A QUALITY PART

Now that we know 3D printing can make quality parts for end use applications at scale, what are the main elements to consider to achieve the perfect finish?

1. Technology & Material

The first step is to choose the right technology and material to achieve the desired surface quality. For polymers the three main technologies are FDM/FFF, SLS and SLA. While each builds a part layer-by-layer, they differ in their resolution and each have different design limitations. Choosing the technology and material is the first step to creating a part with a quality surface finish.

2. Design

A 3D printed part with a quality surface aspect starts with a thoughtful 3D design adapted to technology and material limitations. With 3D printing, design complexity is no longer constrained by traditional manufacturing methods. Complex geometries, lattices, and textures can be applied to any form to create truly unique designs.

PA12 - SLS, Various finishes

3. Post-processing

The advancement of post-processing solutions for 3D printed parts has unlocked the potential of 3D printing for almost any application. Finished parts have the look and feel of traditional injection molding for end-use consumer goods, drones, robotics, prosthetics, or any other visible part. Additionally, these post-processing solutions can enhance the mechanical performance of parts, provide protection from UV rays, and even make them waterproof.

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TECHNOLOGY & MATERIAL

KEY CONSIDERATIONS

During the first steps of the manufacturing process, the choice of material and technology play an important role in the part's overall surface aspect. There are some aspects to consider while making this essential choice.

1 Resolution

The 3D printing resolution is an indication of the accuracy of the 3D printer, which will directly determine the quality of the 3D printed part. It is described in 3 different dimensions: X, Y and Z. The horizontal resolution (XY) is the planar dimension, the smallest movement the laser of the 3D printer can make in one layer. The smaller the movement, the better the details. The vertical resolution (Z) is the layer height or layer thickness.

2 Size of part

The size of the part is an important consideration when selecting the 3D printing technology. Higher resolution technologies such as DLS, LCD, DLP, or SLA typically have smaller build volumes than powder bed fusion or FFF printers.

Ultracur3D® RG 35 - DLP, Coating finish (Source: Forward AM)

3 Layer thickness

Layer thickness in 3D printing is a measure of the layer height of each successive addition of material in the additive manufacturing process in which layers are stacked. SLA 3D printing process is able to achieve smaller layer thicknesses, the reason for the improved print quality lies in their much higher XY-resolution.

4 Material properties

Not every material is compatible with all kinds of finishes. Rubber-like plastic parts can't handle the same finishes as traditional Nylon PA12. Indeed, the adapted finishing will also depend on the surface of the raw material.

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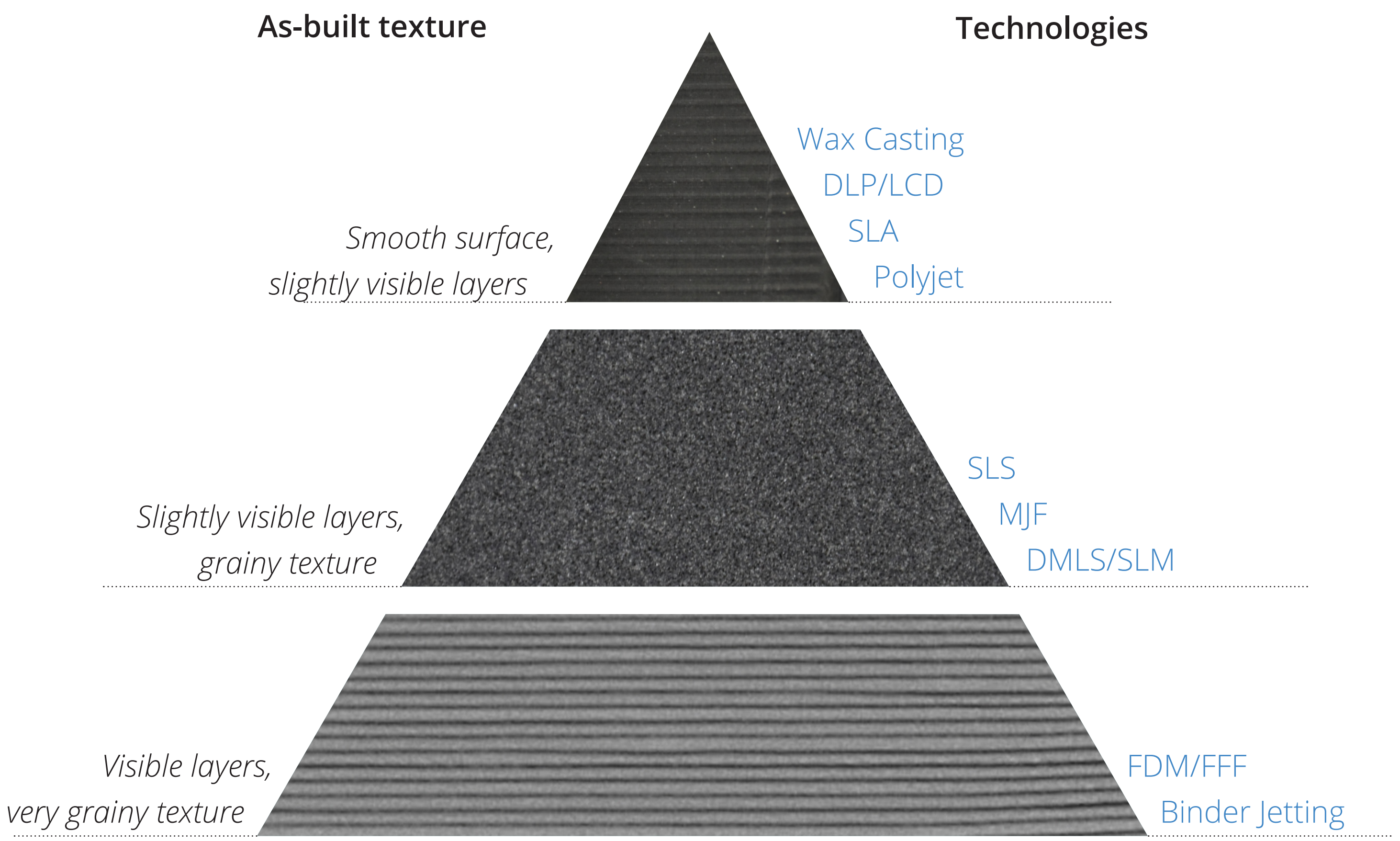
THE HIERARCHY OF 3D PRINTING SURFACE QUALITY

As-built surface quality refers to the raw (unfinished) surface of a part after being printed. Surface quality is an essential aspect to consider before post-processing, as it will affect the final result of your project. The main factor to consider is the technology you are planning to use. It is important to note that **surface quality will have to be balanced against scale and cost** when choosing the technology for your project.



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SURFACE QUALITY AT SCALE

Surface quality and scalability are often seen as being in competition when it comes to additive manufacturing. But, with powder bed fusion and large format LCD technologies, quality at scale is a reality.

	PA12	TPU	EPD 1006	PA11
Technology	SLS & MJF	SLS & MJF	LCD	SLS & MJF
Properties	Versatile	Flexibility	Waterproof	Bio-sourced
Post-processing options	Polish Chemical smooth Color touch Metalization Coating	Chemical smooth Metalization Coating	Sanding Metalization Coating	Polish Chemical smooth Color touch Metalization Coating
Raw color				
Raw surface quality	Grainy Porous	Grainy Porous	Smooth	Grainy Porous
Supports required	✗	✗	✓	✗
Batch throughput	SLS 600 340 340 MJF 380 380 284 Large Build Volume	SLS 600 340 340 MJF 380 380 284 Large Build Volume	280 510 Large Build Tray	SLS 600 340 340 MJF 380 380 284 Large Build Volume
Cost	**$$**$$$	**$$$**$$	**$$$**$$	**$$**$$$

Summary

- Overall, powder bed fusion technologies provide a consistent starting point however, industrialized post-processing is recommended for a more refined touch/feel.
- Resin technologies (DLP/LCD, DLS, SLA) offer a better raw surface finish but present with fewer possibilities for post-processing.

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DESIGN

FIRST STEPS

The surface quality of your part starts with the design process, but there are some important first steps to consider:

1. Choose your technology, material, and post-processing

The choice of material, technology, and post-processing with necessarily influence the design process and play a critical role in the outcome of the part. The design has to be adapted to the specific requirements of the technology, taking into consideration the need for supports or manufacturing constraints. With respect to material choice, this will inform the potential post-processing options and ultimately the final look.

Ultracur3D® EPD 4006 - LCD, Unfinished

2. Respect the design guidelines

While 3D printing removes many limitations of traditional manufacturing, there are still some constraints to follow to ensure the design can be manufactured. Design guidelines for each technology and material such as minimum wall thickness, feature size, and tolerance reduce the risk of failed parts and defects during production. It's also important to consider the constraints of the post-processing since these processes could damage fragile design elements.

3. Pay attention to your 3D file

Even after designing the perfect 3D model which respects the design guidelines of the chose material/ technology, turning this 3D model into a physical object involves converting the software's native CAD format into one that can be communicated to the printer. This process is called meshing and it plays a direct impact on the surface quality of the part. The higher the quality of the meshing the higher the resolution of the print. Meshing is particularly important on round surfaces to avoid seeing faces on the final part.

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DESIGNING FOR TECHNOLOGIES

Each 3D printing technology presents a unique set of challenges to consider when designing parts with the ideal surface finish. Consider the best practices below as you prepare your design.

FFF & Photopolymer Technologies

- Avoid curved surfaces and low angle slopes in the Z direction, resulting in visible steps between layers.
- Minimize support structures especially on important surfaces. The more your model is in contact with supports, the more likely their removal may result in marks or breaks.

Powder Bed Fusion Technologies

- Curved surfaces and low angle slopes in the Z direction will cause visible steps.
- Dense parts or thick walls greater than 15mm can cause surface damage due to thermal issues during the cooling process.
- For MJF technology, anticipate downskin (smoother) and upskin (leaves sharper edges and grainier surface). Orient important faces downwards.
- Abrupt changes in thickness, such as ribs behind a surface can be visible through the surface, due to thermal shrinking.
- Powder can be difficult to extract from designs with fine details, textures, or engraving.

Ultracur3D® EPD 1086 - LCD, Unfinished

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Ultracur3D® EPD 1086 - LCD, Unfinished

DESIGN COMPLEXITY: MINIMIZING SURFACE AREA

A main advantage of 3D printing over traditional manufacturing methods is to create detailed, complex parts rather than large smooth surfaces with no details. Designers and engineers have been taught to design for traditional manufacturing, but this doesn't necessarily transfer to 3D printing; what if the best surface was no surface at all? With 3D printing, hollow forms and lattices not only provide functional optimizations, they can also improve the surface aspect by removing excess material.

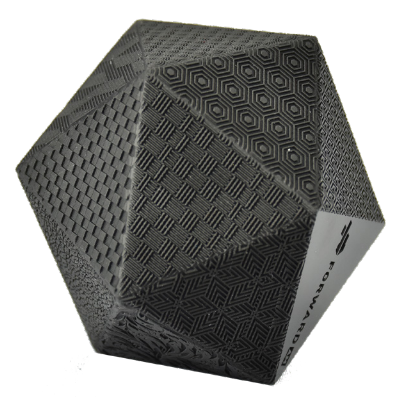
Lattices: A structure with many advantages

A lattice structure forms a network of crosshatch sections that strengthen the whole structure of a part. Lattices allow for lightweight but strong structures by minimizing the amount of material. How does this improve the surface aspect of parts? Less material means less risk of thermal defects during the cooling process. Less surface area also means fewer visible layers and less area to post-process. Aside from these practical benefits of lattices, they also add visual interest and unique design, showcasing the advantage of 3D printing for complex geometries.

THE POSSIBILITIES OFFERED BY TEXTURE

The question of 3D printing surface quality has always centered on making parts as smooth as possible, eliminating layer lines, and having the look and feel of injection molded parts. While 3D printing and post-processing technologies have certainly made advances in this regard, it's also possible that what was once considered a "bug" could rather be considered a feature of 3D printing if we make the most of surface textures in the design process. In fact, if used creatively, texturing can even be a great advantage of 3D printed parts over injection molding.

Integrating textures on injection molded parts is a costly and complex process involving etching of a texture into a physical mold. Custom textures can be designed directly into the CAD file allowing for more flexibility and infinite design possibilities. With 3D printing, a textured part costs the same to produce as a smooth one while unlocking new potentials for designed surfaces.



Ultracur3D® EPD 1006 - LCD, Unfinished

How does it work?

1. Texture is either imported from a texture library or created from a picture using grey levels converted to a depth map
2. Using CAD software such as Rhino, Zbrush, Blender, 4D additive, or Solidworks the 2D image is mapped onto the 3D file by UV mapping
3. The texture is directly integrated into the geometry of the 3D file which can be sent for production. Alternatively, the texture can be applied directly in the slicing process in Cura or Carbon pre-process software

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Why add texture?

Texture is another piece of the puzzle to achieve a high quality surface on 3D printed parts. There are two main reasons to integrate texture: aesthetics and function.

Aesthetics:

Even the highest resolution 3D printing technologies will still leave some slightly visible layers, using surface textures can camouflage these traits of the 3D printing process. With some clever texturing, 3D printed parts are indistinguishable from injection molding and can even offer other advantages such as branding or creating a uniform style across product lines.


PA12 - SLS, Unfinished

- Cover layers or other surface imperfections
- Mass-customization of personalized surfaces
- Branding a recognizable pattern/logo into products
- Mimic natural materials (i.e. leather, wood grain)
- Add visual interest
- Reduce glare or create matte surfaces

Function:

Texture can also provide significant advantages when if comes to the function of end use parts. There are three main scenarios where texture can improve the function: using texture to improve the friction of a handle with a textured grip, texturing large surfaces to improve the stiffness and strength of parts, without adding material by increasing wall thickness, and finally, to create so called “high-performance surfaces”, specially designed surfaces that improve water or air flow, reducing surface tension, or optimizing fluid distribution for example.

- Grips for robotics/end-effector applications
- Traction for sliding surfaces/ wet environments
- Lattice/grids for light or sound applications
- Strengthen thin walled parts without adding weight
- Positioning/informational guides
- Water/air flow optimization


Ultracur3D® ST 45 B - DLP, Unfinished

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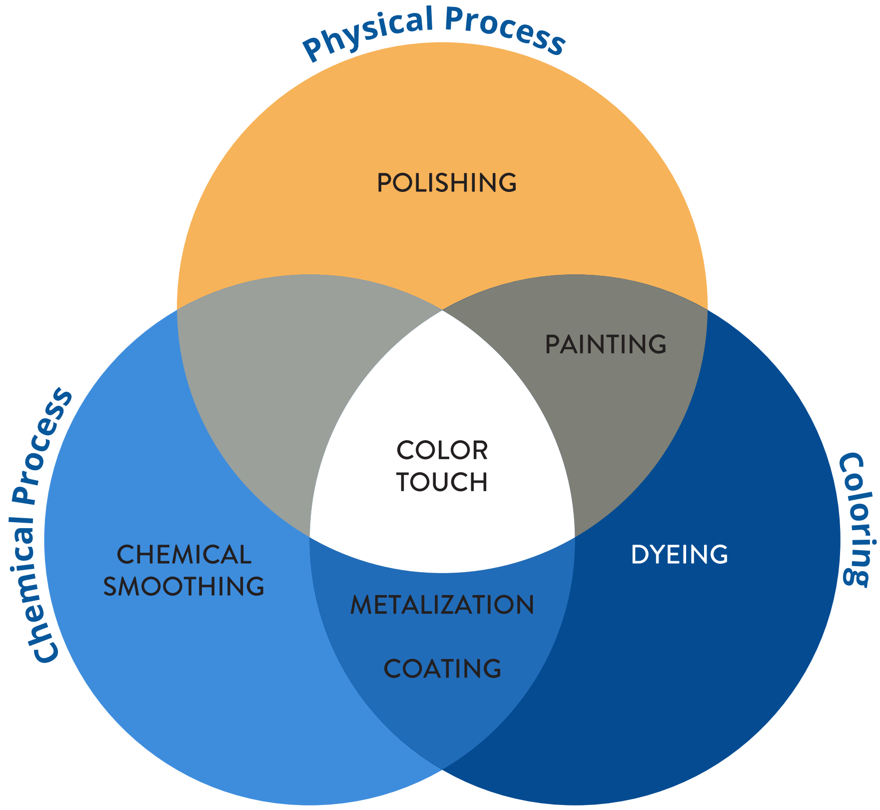
POST-PROCESSING



Which options exist today?

With the growing use of additive manufacturing for production, and its adoption by different industries, new finishes are constantly being developed for the most demanding applications. The keys are consistency and quality of finished parts at any scale of production.

Factors to consider

As we've seen, design and the choice of material play an important role in the finished look of a part. But, there are other factors to consider regarding the actual use of the part.

Many finishes not only enhance the visual aspect of the part but also improve mechanical properties or provide protection from environmental conditions. Today's post-processing solutions can provide UV resistance, chemical resistance, waterproofing, food safety or bio-compatibility.

However, there are still some constraints to consider which will influence your choice of post-processing solution. In this section, we outline the different solutions and explore the important factors to consider when choosing a finishing option.

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COMPARING POST-PROCESSING SOLUTIONS

To make an objective comparison between the readily available post-processing options, we'll examine three different aspects for each finishing solution.

1 Visual Appearance

To compare the effects of different finishing techniques, we will refer to a 3D printed test piece which features common surfaces and textures. The benchmark test piece is printed in PA12 using SLS technology. This test piece can also serve as a guideline to identify design constraints to keep in mind for each post-processing solution.

2 Mechanical Properties

To create a consistent and structured comparison, we will focus on three key mechanical properties: elongation at break, Young's Modulus and tensile strength of untreated and finished tensile bars in PA12 SLS and TPU MJF. These tests will help to understand how post-processing affects the mechanical properties.

3 Surface Roughness

Testing the Ra of a flat surface indicates the evenness of the surface. We'll compare surface roughness before and after post-processing our PA12 SLS benchmark test piece.

***Ra (Roughness Average) is the most common metric used to calculate roughness of a surface. It is calculated measuring the deviation of surface heights and depths across the surface.*

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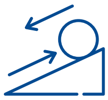
POLISHING

Polishing is a broad category of finishing which smooths rough surfaces by friction with an abrasive. Tumble polishing uses rotation and vibration of parts with an abraisive media. Another form of polishing used for 3D printed parts is abrasive blasting, where a part is blasted by an abrasive media under high pressure.

Material Compatibility:

- All polymers & metals



Reduce friction

Easier to clean

Tips:

- Avoid fragile parts with small details or overhangs
- Large flat surfaces can be difficult to polish in a rotating tumbler
- Abrasive may be logged in hollow parts or parts with small openings

How does it work?

01 The 3D part is added to a cauldron, filled with polishing stones that rotate and vibrate.

02 The part is brushed by the rotating and vibrating stones for 3-5 hours softening rough surfaces and smoothing layer lines.

03 Once the part is removed, a technician attempts to remove any small stones which may be trapped inside hollow cavities.

POLISHING CLOSER LOOK

	PA12 SLS	
Mechanical Properties	Raw	Polished
Surface Roughness (µm)	5.7	3.9

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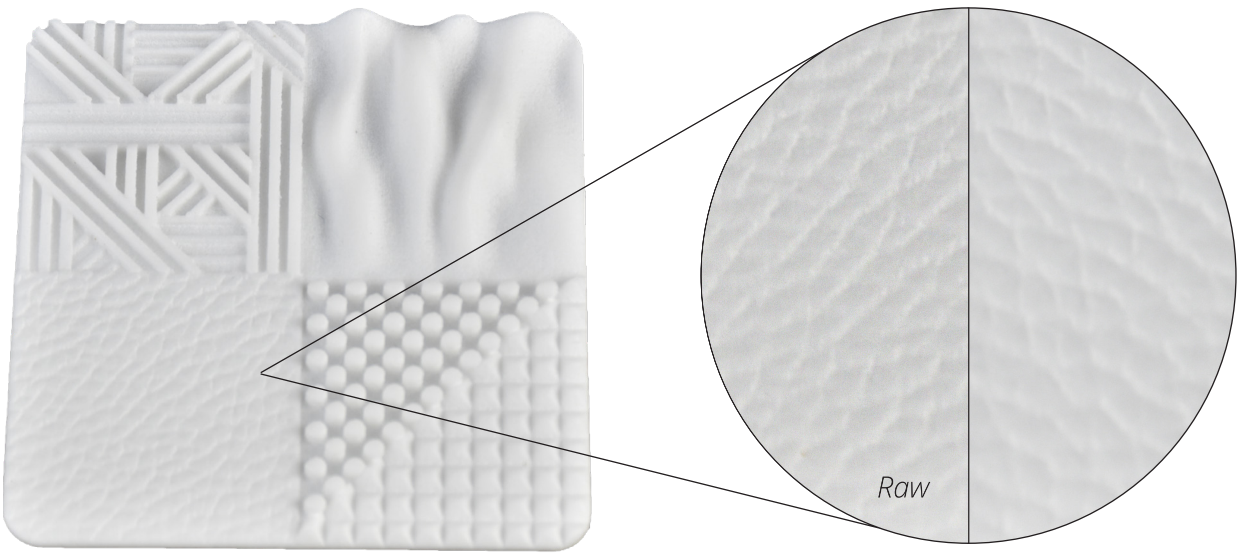

Polishing considerably improved the surface roughness of the test part. We notice a slight rounding of the pointed features of the test piece. No other imperfections on the rest of the features are noticeable.

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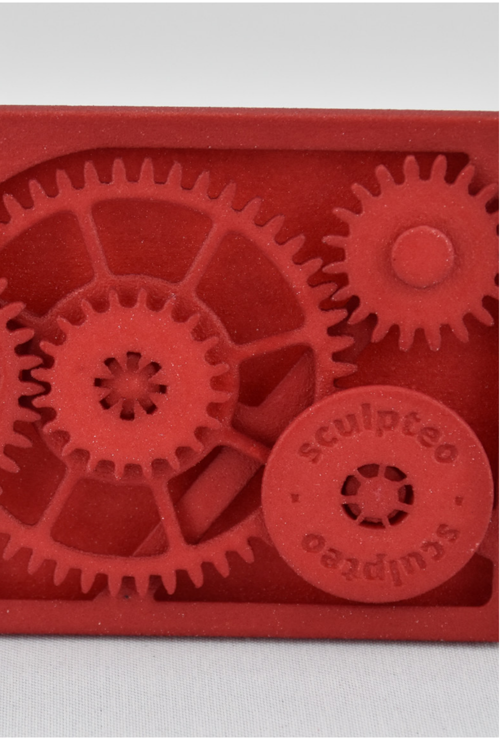

DYEING

The dyeing process allows colors to penetrate the surface of the part. Liquid dyeing ensures that color evenly reaches all surfaces of the parts including small cavities, lattices, and hollowed parts.

Material Compatibility:

- Polyamides
- Polyurethane
- Elastomer
- Acrylic
- Polyester
- TPU
- PEEK
- ABS

Wide range of colors

Tips:

- Colors may fade over time
- Not recommended for exterior environments (UV light, wet conditions)

How does it work?

01 A concentrated liquid dye base is diluted with water and heated to 87°C.

02 Parts are immersed in the dye bath for 5-10 minutes to allow the color to infiltrate the parts.

03 A technician removes the parts and gently washes the parts to remove excess dye. The parts are then dried to allow the dye to set.

DYEING CLOSER LOOK

	PA12 SLS	
Mechanical Properties	Raw	Dyed
Surface Roughness (μm)	5.7	6.0
Youngs Modulus (MPa)	1552	1417
Tensile Strength (MPa)	46	44
Elongation at Break (%)	15	19

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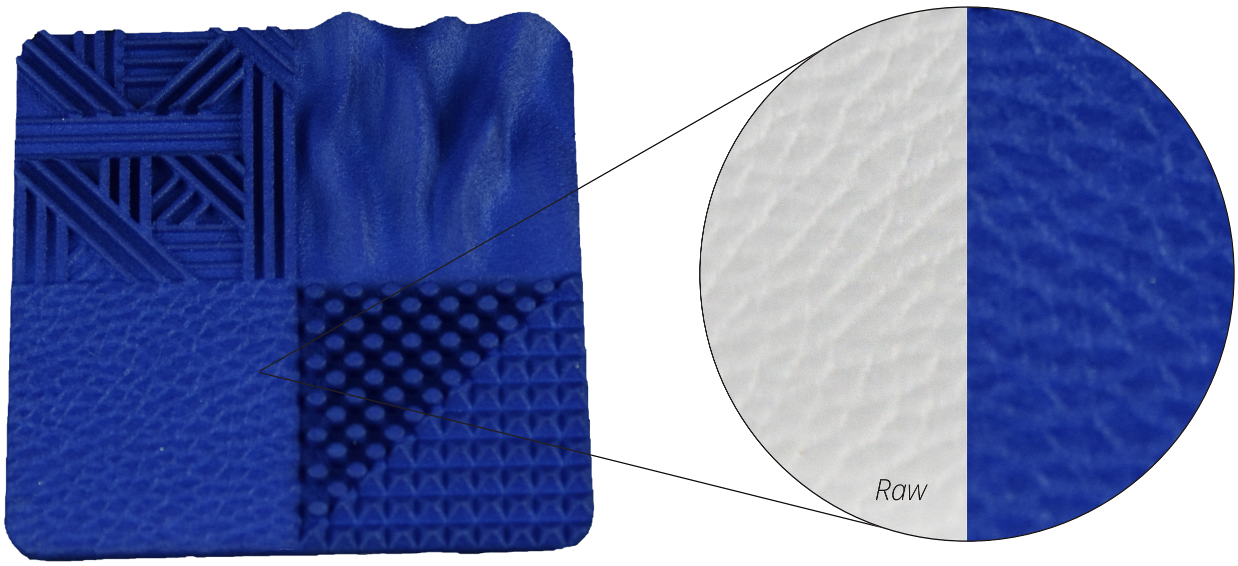

The dyeing process results in a lower Young's Modulus and a higher Elongation at Break. Dyed parts are softer and more flexible. The surface roughness has also slightly increased after treatment. The deep blue highlights the leather texture and emphasizes the relief of the other features.

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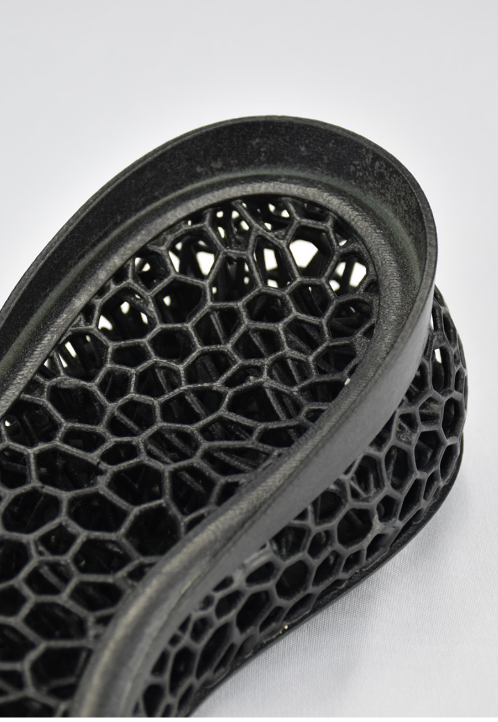

CHEMICAL SMOOTHING

Chemical Smoothing uses a vapor solvent to smooth and seal the surface creating a water and air tight part. This process creates a glossy smooth surface allowing for easier cleaning and reduced bacteria growth. It can also be combined with coating for a more uniform surface.

Material Compatibility:

- All polymers

Less porous

Waterproof

Glossy

Tips:

- Avoid parts with high variation in density
- Avoid fragile parts or parts with tight cavities
- Parts must be suspended within the machine

How does it work?

01 An initial tumble polishing removes loose material and rough surfaces.

02 Parts are suspended on small wires or hooks to ensure the solvent can penetrate every surface evenly inside the PostPro 3D by AMT.

03 The PostPro 3D vaporizes a chemical solvent which condenses on the surface of the part. The vapor reacts with the polymer, sealing pores and creating a smooth, glossy surface. The parts are dried in the processing chamber and then extracted from the machine ready for use.

CHEMICAL SMOOTHING CLOSER LOOK

	PA12 SLS		TPU01 MJF	
Mechanical Properties	Raw	Chemical Smoothing	Raw	Chemical Smoothing
Surface Roughness (µm)	5.7	1.7	-	-
Youngs Modulus (MPa)	1552	1425	88	88
Tensile Strength (MPa)	46	45	8	8
Elongation at Break (%)	15	18	189	196

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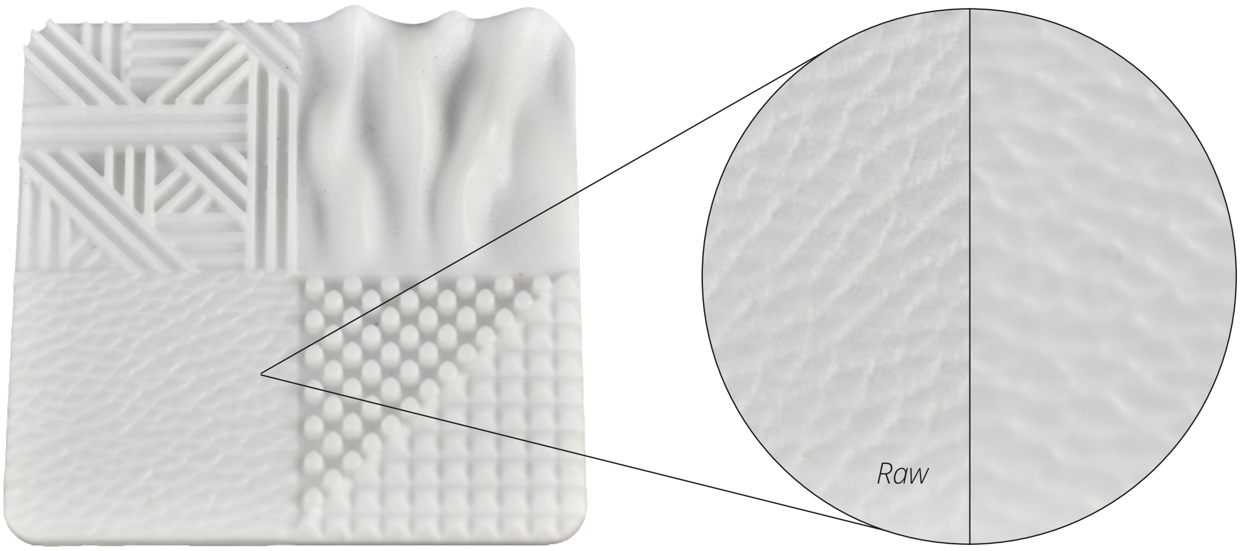

Chemical Smoothing drastically improves the surface roughness of the test piece. With a lower Young's Modulus and higher Elongation at Break, parts are more flexible and softer for PA12. There were no significant differences in the mechanical properties of TPU. The features of the test part have a slightly glossy finish, without any alteration to the geometry.

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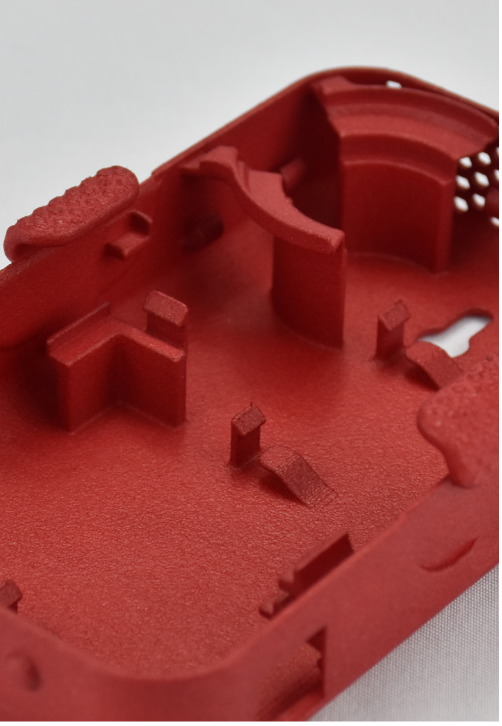

COLOR TOUCH

The Color Touch process uses specialized dyeing technology to deeply infiltrate color into parts. DyeMansion coloring ensures certified colors and consistent finishing across production batches. The deeper coloring minimizes fading when exposed to UV light and heat and increases scratch resistance.

Material Compatibility:

- All polyamides

Scratch resistant | UV resistant | Skin safe | Light and heat resistance

Tips:

- Avoid fragile parts with small details or overhangs
- Large flat surfaces can become warped
- Abrasive may be logged in hollow parts or parts with small openings

How does it work?

01 An initial tumble polishing and shot peening remove rough surfaces and ensure uniform dye penetration.

02 The parts are placed in the DyeMansion's DeepDye Coloring technology, using a specialized dye cartridge the preset program runs for 1.5 - 2 hours. Using heat and pressure the dye infiltrates the surface up to 200 µm.

03 A final shot peening with ceramic beads ensures a perfectly smooth surface.

COLOR TOUCH CLOSER LOOK

	PA12 SLS	
Mechanical Properties	Raw	Color Touch
Surface Roughness (μm)	5.7	3.5
Youngs Modulus (MPa)	1552	1499
Tensile Strength (MPa)	46	45
Elongation at Break (%)	15	16

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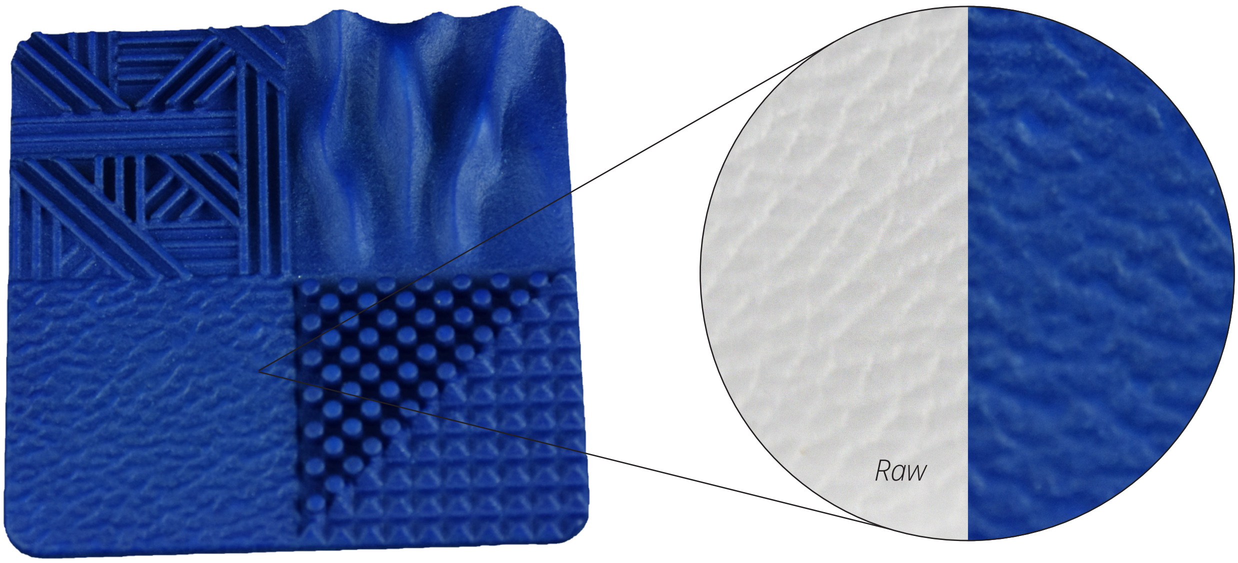

The Color Touch process has greatly reduced the surface roughness while also decreasing the Young's Modulus to make the test part slightly more flexible. We notice a slight softening of edges and pointed features of the test piece.

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METALIZATION

Metalization is the process of depositing a thin layer of metal onto the surface of an object by electroforming. Polymer parts take on the visual characteristics of a metal surface without the weight of a full metal part. This process can add up to several milimeters to the surface.

Material Compatibility:

- All polymers
- All photopolymers

Corrosive resistant | Waterproof | Lightweight | Airtight

Tips:

- Small details may be lost due to the metal layer
- Any surface imperfections will be amplified, ensure a smooth surface

How does it work?

01 An initial tumble polishing removes rough surfaces and a conductive layer is applied.

02 An electrical contact is made on the part creating an oxidation-reduction of metal ions preparing the part to receive the metal surface.

03 The part is immersed in a copper or nickel bath, the time spent in the bath will determine the thickness of the deposited metal (from a few microns to several millimeters).

METALIZATION CLOSER LOOK

	PA12 SLS		TPU01 MJF	
Mechanical Properties	Raw	Metalization	Raw	Metalization
Surface Roughness (µm)	5.7	0.2	-	-
Youngs Modulus (MPa)	1552	1593	88	160
Tensile Strength (MPa)	46	47	8	8
Elongation at Break (%)	15	10	189	185

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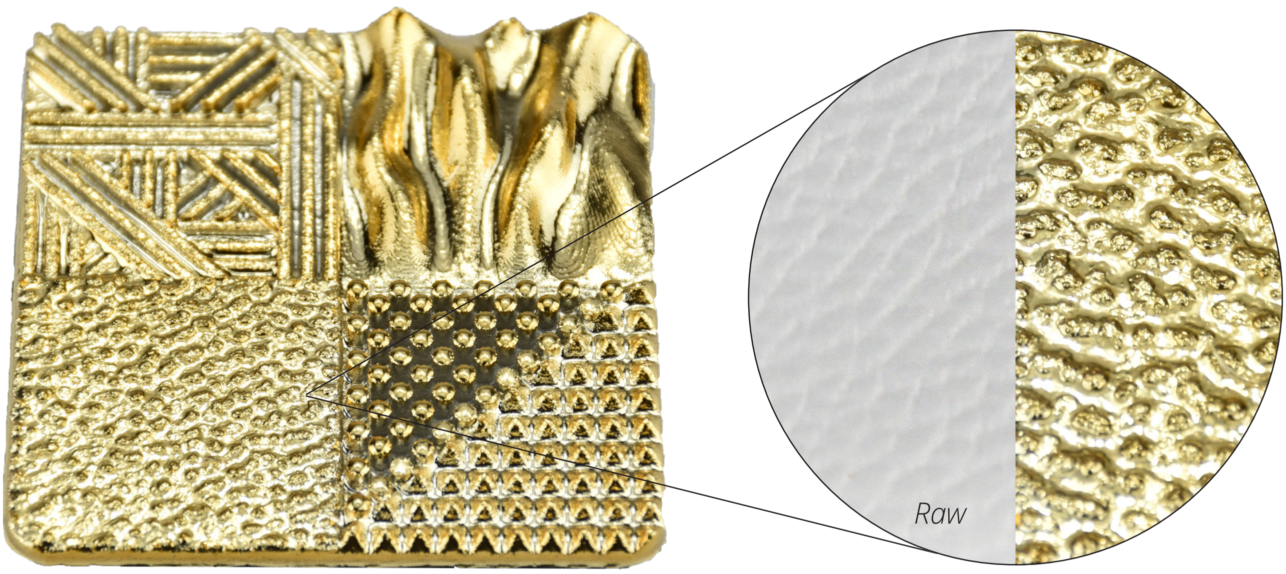

Metalization has dramatically reduced the surface roughness, making the best surface treatment of all post-processes we tested. Metalization also lowered the elongation at break for PA12 while an increase of stiffness is noted for TPU parts. The testing process caused the metalization surface to crack for TPU tensile bars. The surface of the wave features resulted in a quality finish after metalization, however, the other test features with finer details resulted in rough edges and inconsistent metalization in deeper textures.

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COATING

This surface treatment covers the accessible surfaces of a part with a polymer based coating. The coating doesn't penetrate the surface but forms a strong adhesion due to a chemical bond. Coating can be made in a wide variety of colors and also improve the properties of the part to be able to withstand tough environmental conditions.

Material Compatibility:

- All Polyamides
- TPU

UV resistant

Skin safe

As flexible as the material

Tips:

- Small details may be lost due to the coating layer
- Very complex geometries which are difficult to access are not recommended

How does it work?

01 An initial pre-treatment removes rough surfaces and layer lines ensuring a uniform surface. The part is then thoroughly cleaned to ensure maximum adhesion.

02 A primer is applied by spray gun to help the spray coating adhere to the part.

03 A technician manually applies a spray coating from all angles. The coating forms a chemical bond preventing peeling or cracking. Depending on the color, multiple layers of coating may be applied.

COATING CLOSER LOOK

	PA12 SLS		TPU01 MJF	
Mechanical Properties	Raw	Coating	Raw	Coating
Surface Roughness (µm)	5.7	3.2	-	-
Youngs Modulus (MPa)	1552	1468	88	82
Tensile Strength (MPa)	46	44	8	8
Elongation at Break (%)	15	14	189	177

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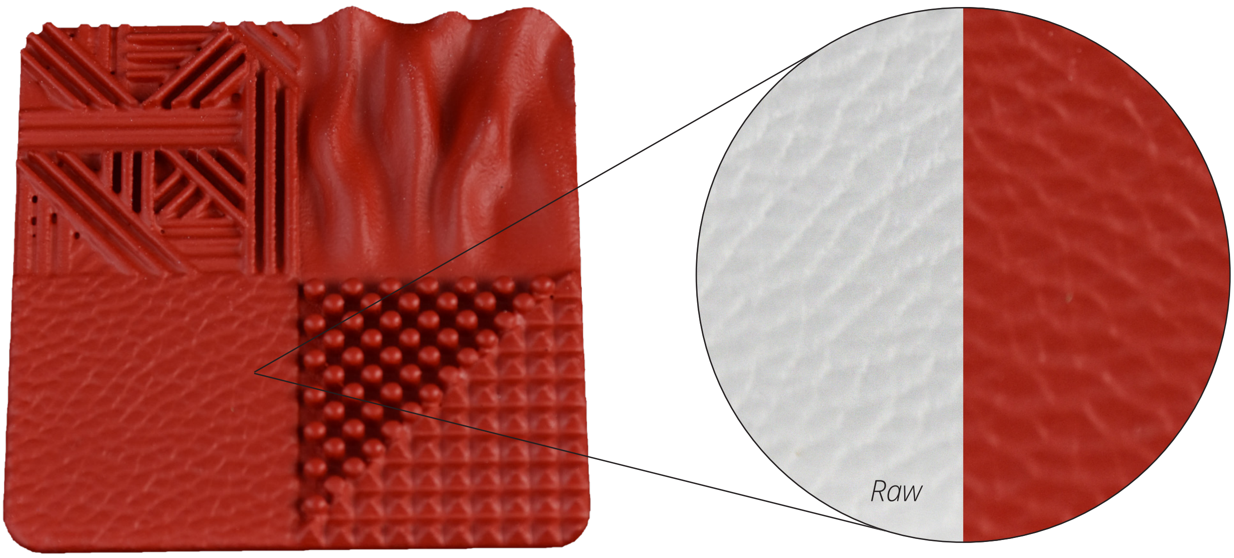

Coating greatly improved the surface roughness of the test piece and also resulted in a softer, more flexible PA12 part. For TPU there was no significant difference in mechanical properties. The waves and leather texture features produce a suitable finish after coating. More profound textures with tight gaps leave visible imperfections where an uneven coating application suppresses the texture.

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PUTTING IT ALL TOGETHER

We started by looking at three myths of 3D printing, now that we've seen what's truly possible, let's take a look at the three realities of 3D printing:

1

Quality 3D printed parts are here to stay. With the development of technologies, materials and finishes, additive manufacturing has become a real manufacturing solution to produce quality finished parts at scale.

2

Budget, quantity, and surface quality are (somewhat) in competition. While it is possible to have a high definition surface quality for 3D printed parts, the scale of production could make this cost prohibitive. Choosing a technology that can scale would marginally reduce the surface aspect while keeping the budget in check.

3

Consistent quality is best left to the professionals. A professional Additive Manufacturing partner has the knowledge and experiece of working with different technologies to deliver quality parts. A trusted production partner can deliver to your expectations, from choosing the right material to Design for Additive Manufacturing to industrialized post-processing.

Ultrasint® TPU01 - MJF, Chemical Smoothing

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MAKE YOUR BUSINESS THRIVE WITH 3D PRINTING

Access our
MasterClass resources
and develop your AM strategy

Think additive & Gain an adaptive advantage for your business.

Access to a one-stop-shop of resources to discover your Additive Advantage and develop a strategy that will **put game-changing technology into your hands**.

Use it to unlock the full potential of 3D printing, and:

- **Create room for innovation,**
- **Scale your production,**
- **Make adaptability one of your greatest strengths**.

We've compiled our best ebooks, playbooks, guides, and customers' stories, made for professionals who want new additive manufacturing opportunities

...all in one place.

sculpteo

A brand of BASF - We create chemistry

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