Advanced 3D Printing

WITH THE AGGIE INNOVATION SPACE

AIS Capabilities

Fused Deposition Modeling (FDM)

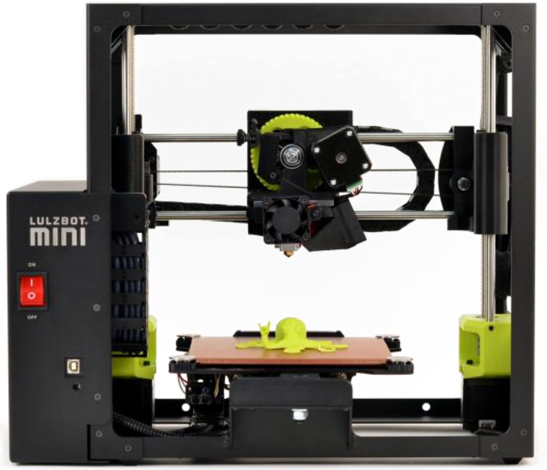
Industrial FDM

Stereolithography Apparatus (SLA)

PolyJet

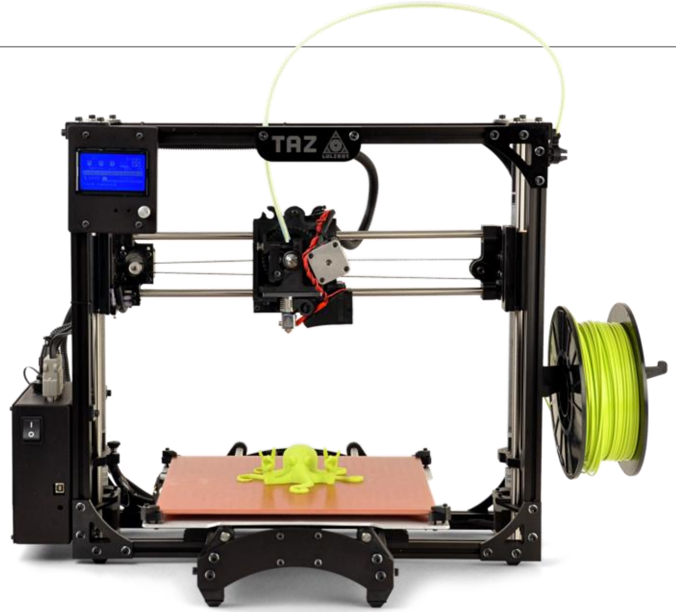
Selective Laser Sintering (SLS)

FDM



Lulzbot Mini 2

- Build volume: 6.3” x 6.3” x 7.09”
- Nozzle diameter: 0.5mm
- Filament diameter: 3.00mm
- Max bed temp: 120C
- Max melt temp: 290C
- Slicing software: Cura - Lulzbot



Lulzbot Taz 5

- Build volume: 11.7” x 10.8” x 9.8”
- Nozzle diameter: 0.5mm
- Filament diameter: 3.00mm
- Max bed temp: 120C
- Max melt temp: 290C
- Slicing software: Cura - Lulzbot

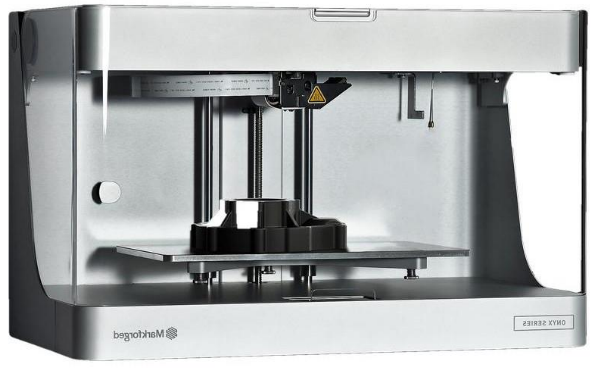
Ultimaker 3

- Build volume: 8.5” x 8.5” x 7.2”
- Nozzle diameter: 0.4mm
- Filament diameter: 3.00mm
- Max bed temp: 100C
- Max melt temp: 280C
- Dual extrusion
- Slicing software: Cura - Ultimaker

Ultimaker 2+

- Build volume: 8.8” x 8.8” x 12”
- Nozzle diameter: 0.4mm and 0.6 mm
- Filament diameter: 2.85mm
- Max bed temp: 100C
- Max melt temp: 260C
- Slicing software: Cura - Ultimaker

FDM



Fusion3 F410
- Build volume: 14” x 14” x 12.4”
- Nozzle diameter: 0.4mm and 0.6mm
- Filament diameter: 1.75mm
- Max bed temp: 140C
- Max melt temp: 300C
- Slicing software: Simplify3D
- Enclosed Chamber
    - Stable temperature (45C) environment
- Filament runout detection

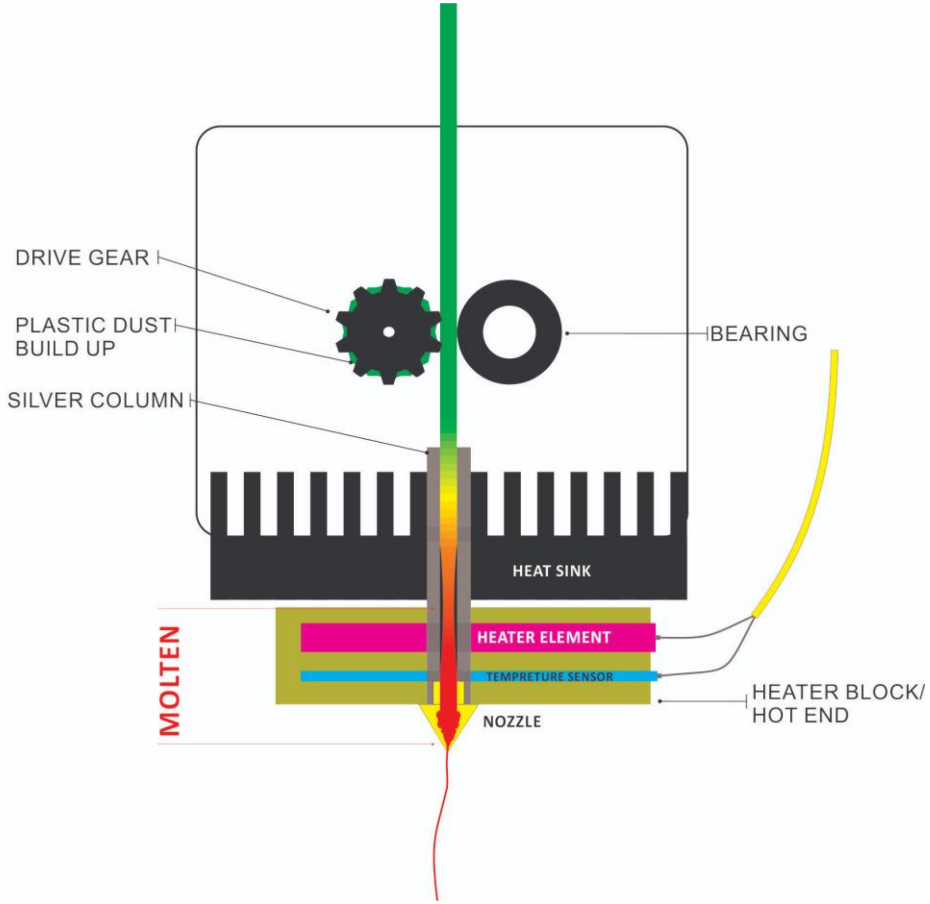
Markforged Mark Two
- Build volume: 12.6” x 5.2” x 6.1”
- Nozzle diameter: 0.4mm
- Filament diameter: 1.75mm
- Primary filament: CF Nylon
- Secondary filament: fiber (fiberglass, Kevlar, CF)
- Slicing software: Eiger

Industrial FDM

Aon M2

- Build volume: 18” x 18” x 25”
- Nozzle diameter: 0.25mm, 0.4mm, 0.6mm
- Smallest layer thickness: ~100 microns
- Filament diameter: 1.75mm
- Max bed temp: 200C+
- Max melt temp: 470C+
- Slicing software: Simplify3D
- Enclosed heated chamber: 135C+
- Dual extrusion
- Aluminum and High-Temp PEI build plates
    - PEI: polyetherimide
- No cooling fan

FDM Process



Pros and Cons

- Best for low-resolution, fast prototyping
  - Less accurate, larger layers (~0.05mm to 0.5mm)
- Widest range of materials
- Longer lifetime of materials
- More variables in print settings
- Little-to-no post-processing
- Easily available in the consumer market
- (With Aon) longer print time due to machine preheating

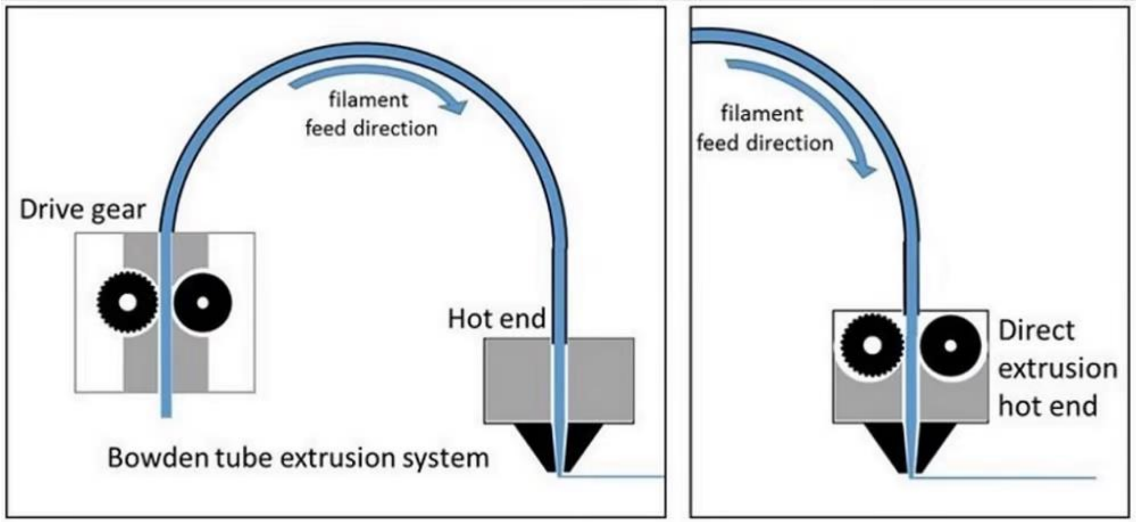
FDM Extruders

Direct Drive Extrusion:

- Extruder mounted on print head, pushes filament directly to nozzle
- Pros: Better retraction, reliable extrusion, wide range of materials
- Cons: Vibrations that could interfere print, difficult maintenance

Bowden Extrusion:

- Extruder mounted to frame, filament goes through "Bowden" tube to nozzle
- Pros: Cleaner movements, smaller printhead = larger print volume
- Cons: Delay in response time between extruder and nozzle, prone to retraction issues and stringing, difficulty printing flexible materials



Stereolithography (SLA)

FormLabs Form 2

- Build volume: 5.7” x 5.7” x 6.9”
- Layer thickness: 25 – 200 microns
- Self-heating resin tank
- 405nm violet laser (250 mW)
- Slicing software: PreForm
- Enclosed chamber

SLA Process

Uses high-powered laser to harden photosensitive resin layer-by-layer through photopolymerization (monomers and oligomers cross-link to form polymers).

Laser directed to coordinates through computer-controlled mirror.

Oldest additive manufacturing technique: Chuck Hull 1984.

Excess resin in tank is continuously re-used.

SLA Post-Processing

1. Form Wash

- Agitated isopropyl alcohol bath
- Removes uncured resin

2. Form Cure

- Cures resin under high wavelength UV light
- Brings material to full strength
- Remove supports prior to curing for easier removal

Pros and Cons

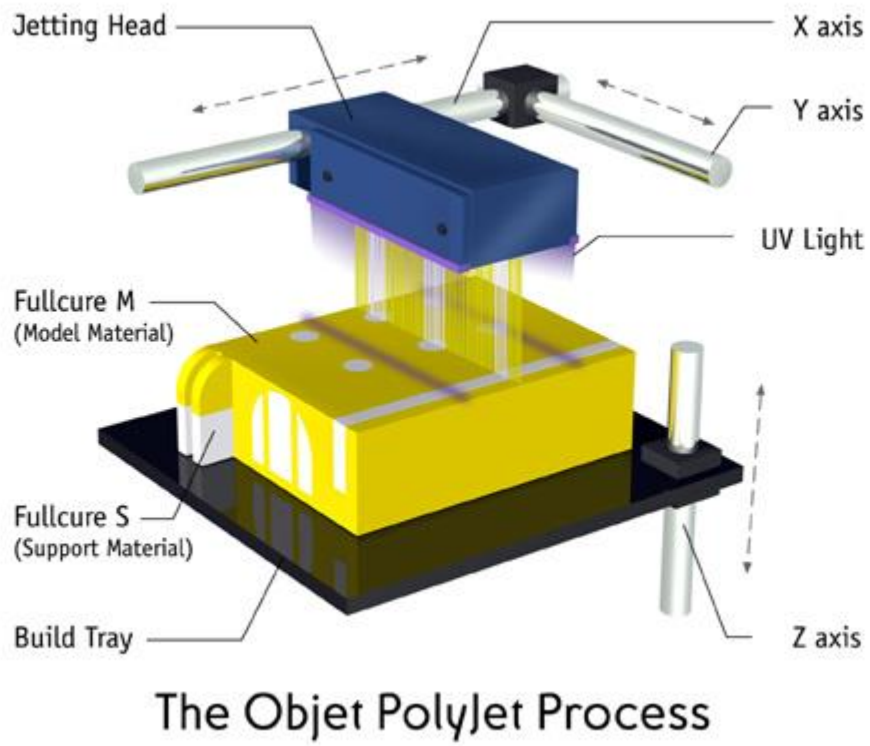
- High resolution layers
- Limited build space
- Less material options (only purchasing through FormLabs)
    - mostly only clear or neutral colors
- Resins can expire quickly
- More expensive compared to FDM
- Some post-processing required
- Failures in resin tank can lead to more difficult clean-up
- No dual material capability

PolyJet

Stratasys Objet30 Pro

- Build volume: 11.57” x 7.55 x 5.89”
- Layer thickness: 16 or 28 microns
- Slicing software: Objet Studio
- Enclosed chamber
- Resin material

PolyJet Process

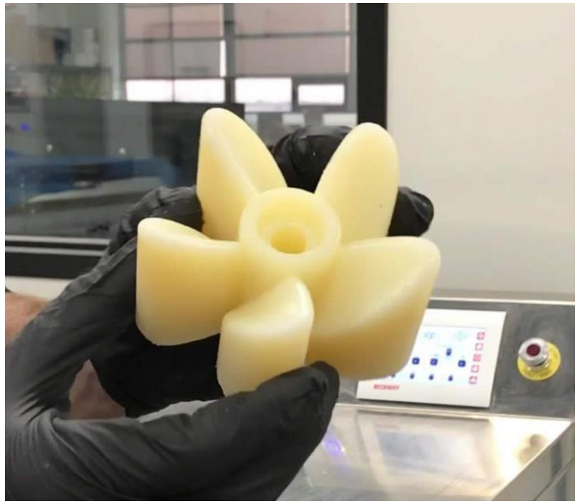


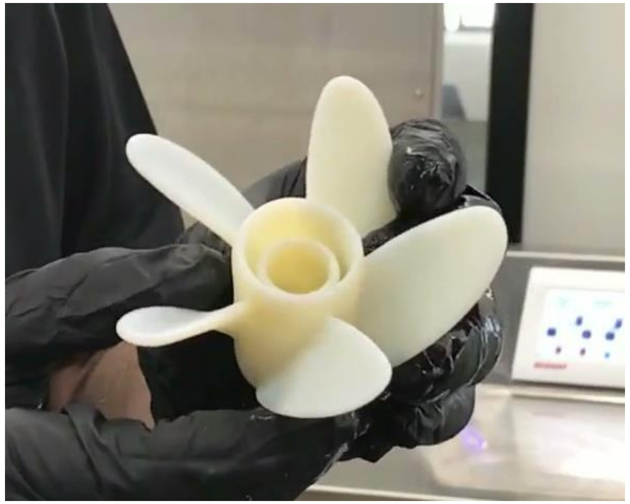
Similar to an inkjet printer. Printer “jets” drops of photosensitive resin that solidify under UV light in layers.

Has multi-material capability for combination of colors or addition of support material.

Excess material is collected into a waste container and cannot be reused as it mixes with other materials.

PolyJet Post-Processing





1. Part is soaked in a sonicator bath with sodium hydroxide to start dissolving gel-like supports
2. Excess cleanup is usually required using brush or high water pressure to scrub off supports

Pros and Cons

- Highest resolution layers
- Less material options (only purchasing through Stratasys)
  - mostly only clear or neutral colors
- Multi-material capability
  - Soluble support material
- Resins expire quickly
  - Longer lead time on prints if new material needs to be ordered
- More expensive compared to FDM
- Post-processing required

Selective Laser Sintering (SLS)

XYZ MfgPro230 xS

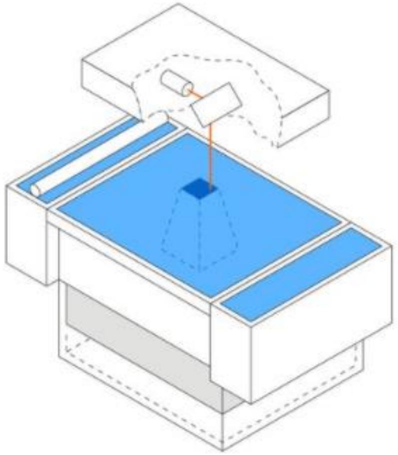
- Build volume: 9” x 9” x 9”
- Layer thickness: 80-200 microns
- CO_2 Laser (30W)
- Slicing software: XYZPrint AM SLS
- Enclosed chamber
- Powder material

SLS Process

A reserve of powder is loaded into the chamber. Wiper moves thin layers of powder from reserve to build chamber.

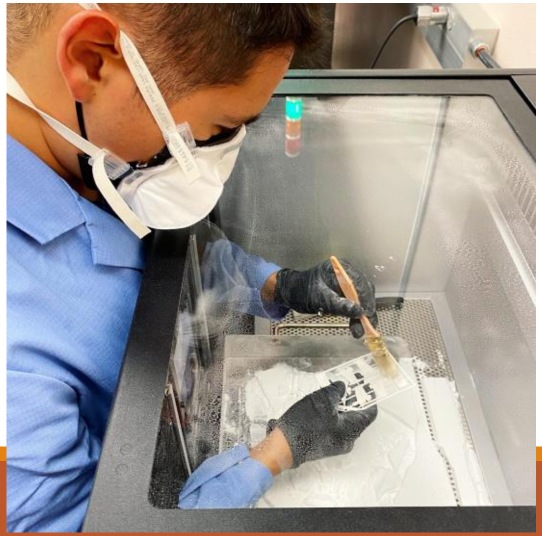
Laser heats the powder to the melting point which fuses the particles together. The platform then lowers to the next layer.

Unfused powder supports part in packed bed.



SLS Post-Processing

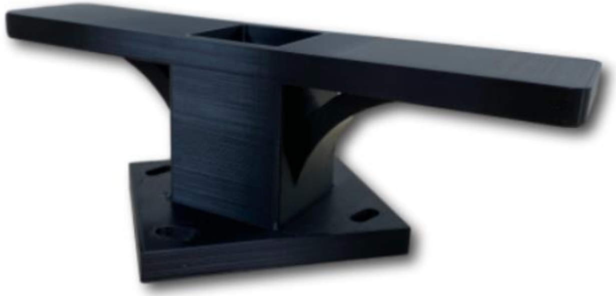
1. Build chamber of powder is removed from printer
2. Excess powder is brushed away from part in de-powdering chamber
3. Compressed air is used to blow away uncured powder that may be stuck to the part
4. “Baked” powder is sieved and mixed with new powder to reuse
5. Final surface finishing can be done in sandblaster



Pros and Cons

- High resolution layers
- Only uses Nylon 12 PA, with some recent expansion in CF and TPU
- Only white powder currently available (can be dyed after printing)
- Material is recycled
- Doesn’t require supports
- Longer print time due to machine preheating and post-processing

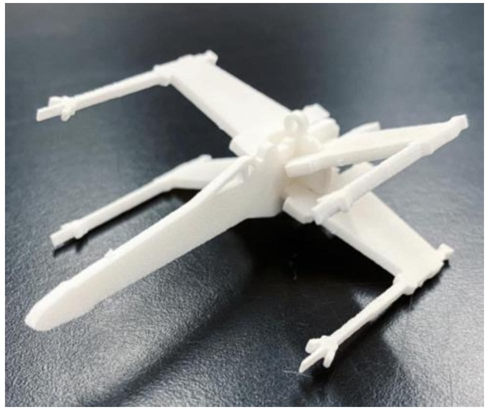
Part Comparison



FDM

SLA

PolyJet



SLS

Material Properties

	Tensile Strength	Glass Transition Temp	Features	Requirements	Printer
PLA	27 MPa	60C	Biodegradable		FDM
ABS	37 MPa	105C			FDM/Aon
Nylon (filament)	66 MPa	70C +	Food Safe	Dry filament	FDM/Aon
PETG	53 MPa	95C	Food Safe		FDM/Aon
PC	77 MPa	145C			FDM/Aon
ASA	43 MPa	100C	High UV resistance		FDM/Aon
TPU	150 MPa	60C	Flexible	Direct extrusion	FDM/Aon
PEEK	100 MPa	143C		Heated chamber, PEI Buildplate	Aon
PEKK	65 MPa	165C	Better layer adhesion than PEEK	Heated, chamber, PEI Buildplate	Aon
ULTEM (PEI)	120 MPa	175C		Heated chamber, PEI Buildplate	Aon

Material Properties

	Tensile Strength	Heat Deflection Temp	Features	Requirements	Printer
FormLabs Clear Resin	65 MPa	66C		IPA Wash, UV curing	SLA
FormLabs Biomed Resin	53 MPa	60C	Biomedically compatible, Able to be sterilized	IPA Wash, UV curing	SLA
FormLabs Engineering Resin	61 MPa	70C	Resists deformation over time	IPA Wash, UV curing	SLA
PolyJet Vero Resin	65 MPa	47C	Food Safe	NaOH wash	PolyJet
Nylon 12 PA Powder	51 MPa	145C	Can be dyed colors	De-powdering chamber	SLS

Materials

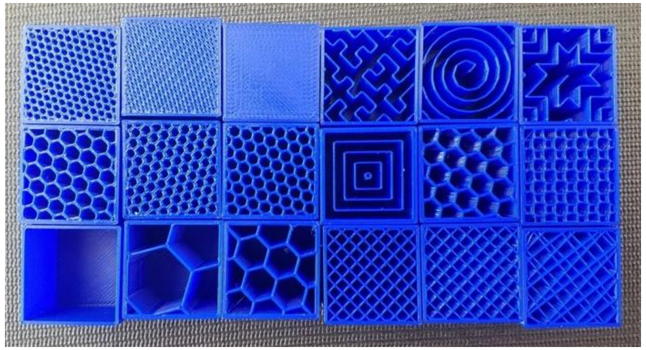
There are so many out there!

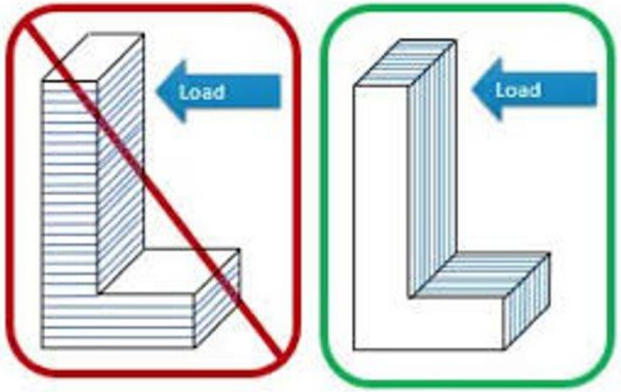
Carbon Fiber infused, copper-fill, glow in the dark, color changing, flexible powder, etc.

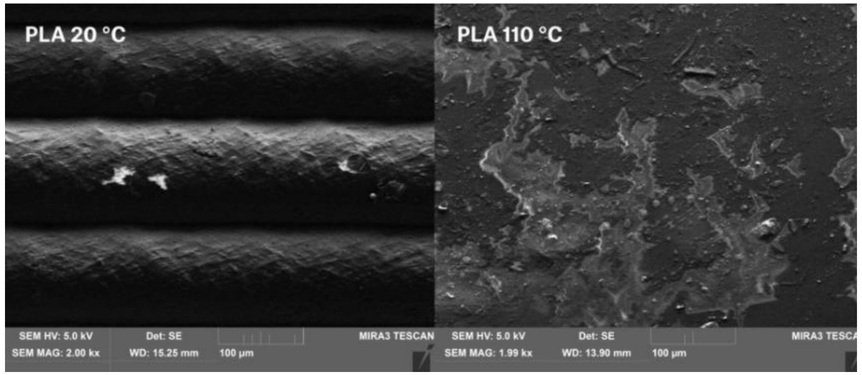
Technical specifications will vary depending on brands, print settings, and storage of the material.

If there is a specific material you would like to use for your project, let us know and we can look into getting it!

Improving on Engineering Specs







Infill Density and Pattern
Different patterns may offer unique points of support throughout the part.

Part Orientation
Consider how load and stress will be applied to your part in reference to how the layers are formed.

Annealing
Heating up a printed part to its glass transition temperature but below its melting point to rearrange the polymer chains so stress is distributed evenly.

Resources on 3D Printing

- https://ais.nmsu.edu
- https://www.simplify3d.com/support/print-quality-troubleshooting/
- https://www.prusaprinters.org/
- https://www.thingiverse.com/
- https://www.tinkercad.com/
- https://grabcad.com/
- https://formlabs.com/
- https://www.matterhackers.com/
- https://www.3dhubs.com/knowledge-base/