

ONYX

General Information

MarkForged's Onyx is a material that is ideal for customer-facing parts that need to look good while standing up to industrial requirements.

Onyx is based on a remarkably tough nylon, but also provides parts with stiffness equal to or greater than any pure thermoplastic material available for professional 3D printers. It's easy to print and far more rigid in assemblies.

Onyx can be used alone, or further reinforced with embedded continuous carbon fiber, Kevlar, or fiberglass layers - parts truly transcending the limits of conventional 3D printed plastic.

The following is useful information regarding printing with Onyx:

- Like all MarkForged materials, parts printed using Onyx are ready for use right off the print bed.
- Onyx has a heat deflection rating of 145°C
- Parts printed in Onyx warp far less than parts printed in Nylon

Material Specifications

The following chart outlines the product specifications for Onyx as well as for Nylon.

Property	Test Standard	Onyx	Nylon
Tensile Strength (MPa)	ASTM D638	36	54
Tensile Modulus (GPa)	ASTM D638	1.4	0.94
Tensile Strain at Break (%)	ASTM D638	58	260
Flexural Strength (MPa)	ASTM D790*	81	32
Flexural Modulus (GPa)	ASTM D790*	2.9	0.84
Flexural Strain at Break (%)	ASTM D790*	N/A **	N/A **
Heat Deflection Temperature (°Celsius)	ASTM D648 Method B	145	44-50
Density (g/cm ³)	N/A	1.18	1.10

*Measured by a method similar to ASTM D790

**Flexural Strain at Break is not available because neither material breaks before the test ends.

NYLON

General Information

MarkForged's Nylon is the standard plastic material that makes up most of any print done on a MarkForged printer.

Nylon is used as a casing for the fiber that is embedded in a part. The outer shell of a part, the inner fill, and any supports in a print are all made up of Nylon.

The following is useful information regarding printing with Nylon:

- Nylon is currently available for the Mark Two and Mark X.
- Nylon must be stored in a dry, airtight environment at all times.

Material Specifications

The following chart outlines the product specifications for Nylon:

<u>Property</u>	<u>Test Standard</u>	<u>Nylon</u>
Tensile Strength (MPa)	ASTM D638	54
Tensile Modulus (GPa)	ASTM D638	0.94
Tensile Strain at Break (%)	ASTM D638	260
Flexural Strength (MPa)	ASTM D790*	32
Flexural Modulus (GPa)	ASTM D790*	0.84
Flexural Strain at Break (%)	ASTM D790*	N/A**
Heat Deflection Temperature (°Celsius)	ASTM D648 Method B	44-50
Density (g/cm ³)	N/A	1.10

*Measured by a method similar to ASTM D790

**Flexural Strain at Break is not available because nylon does not break before the test ends.

CARBON FIBER

General Information

Carbon fiber has the highest strength to weight as well as the highest thermal conductivity. Perfect for applications requiring the greatest possible stiffness and strength.

Material Specifications

The following chart outlines the product specifications for Carbon Fiber:

Property	Test Standard	Carbon Fiber
Tensile Strength (MPa)	ASTM D3039	700
Tensile Modulus (GPa)	ASTM D30309	54
Tensile Strain at Break (%)	ASTM D3039	1.5
Flexural Strength (MPa)	ASTM D790*	470
Flexural Modulus (GPa)	ASTM D790*	51
Flexural Strain at Break (%)	ASTM D790*	1.2
Compressive Strength (MPa)	ASTM D6641	320
Compressive Modulus (GPa)	ASTM D6641	54
Compressive Strain at Break (%)	ASTM D6641	0.7
Heat Deflection Temperature (°Celcius)	ASTM D648 Method B	105
Density (g/cm ³)	N/A	1.4

*Measured by a method similar to ASTM D790

STANDARD FIBERGLASS

General Information

Fiberglass is the most cost-effective material. It's as strong as Carbon Fiber, but 40% as stiff, and 2X the weight. Suited to everyday applications where you need strong parts.

Material Specifications

The following chart outlines the product specifications for Standard Fiberglass:

Property	Test Standard	Standard Fiberglass
Tensile Strength (MPa)	ASTM D3039	590
Tensile Modulus (GPa)	ASTM D3039	21
Tensile Strain at Break (%)	ASTM D3039	3.8
Flexural Strength (MPa)	ASTM D790*	210
Flexural Modulus (GPa)	ASTM D790*	22
Flexural Strain at Break (%)	ASTM D790*	1.1
Compressive Strength (MPa)	ASTM D6641	140
Compressive Modulus (GPa)	ASTM D6641	21
Compressive Strain at Break (%)	ASTM D6641	N/A
Heat Deflection Temperature (°Celsius)	ASTM D648 Method B	105
Density (g/cm ³)	N/A	1.6

*Measured by a method similar to ASTM D790

KEVLAR®

General Information

MarkForged's Kevlar is the most bendable of the fibers that are can be printed with our printers.

Kevlar is a high strength material that is also able to bend or provide some flexibility without snapping.

The following is useful information regarding printing with Kevlar:

- Kevlar is currently available with the Professional and Enterprise kits.

Material Specifications

The following chart outlines the product specifications for Kevlar:

Property	Test Standard	Kevlar
Tensile Strength (MPa)	ASTM D3039	610
Tensile Modulus (GPa)	ASTM D30309	27
Tensile Strain at Break (%)	ASTM D3039	2.7
Flexural Strength (MPa)	ASTM D790*	190
Flexural Modulus (GPa)	ASTM D790*	26
Flexural Strain at Break (%)	ASTM D790*	2.1
Compressive Strength (MPa)	ASTM D6641	97
Compressive Modulus (GPa)	ASTM D6641	28
Compressive Strain at Break (%)	ASTM D6641	1.5
Heat Deflection Temperature (°Celcius)	ASTM D648 Method B	105
Density (g/cm ³)	N/A	1.25

*Measured by a method similar to ASTM D790

HIGH-STRENGTH, HIGH-TEMPERATURE FIBERGLASS

General Information

MarkForged's High-Strength, High-Temperature Fiberglass (HSHT) is a material uniquely designed for users who need strong parts for applications in higher temperature environments, over 105°C.

An example of parts that would need HSHT fiberglass are prototypes that are used in under-hood automotive applications. The exception would be in the engine component itself where the temperature reaches much higher than 140°C.

The following is useful information regarding printing with HSHT Fiberglass:

- Printing with HSHT Fiberglass is approximately 50% slower than printing with Standard Fiberglass.
- If printing with Nylon, is is normal for a slight yellowing of the printed Nylon to occur when printing with HSHT Fiberglass.

Material Specifications

The following chart outlines the product specifications for HSHT as well as Standard Fiberglass:

Property	Test Standard	HSHT Fiberglass	Standard Fiberglass
Tensile Strength (MPa)	Fiber: ASTM D3039 Nylon: ASTM D638	600	590
Tensile Modulus (GPa)	Fiber: ASTM D30309 Nylon: ASTM D638	21	21
Tensile Strain at Break (%)	Fiber: ASTM D3039 Nylon: ASTM D638	3.9	3.8
Flexural Strength (MPa)	ASTM D790*	420	210
Flexural Modulus (GPa)	ASTM D790*	21	22
Flexural Strain at Break (%)	ASTM D790*	2.2	1.1
Compressive Strength (MPa)	ASTM D6641	192	140
Compressive Modulus (GPa)	ASTM D6641	21	21
Compressive Strain at Break (%)	ASTM D6641	N/A	N/A
Heat Deflection Temperature (°Celcius)	ASTM D648 Method B	150	105
Density (g/cm ³)	N/A	1.6	1.6

*Measured by a method similar to ASTM D790