MATERIAL SPECIFICATIONS

COMPOSITES

Markforged

PLASTIC MATRIX	Test (ASTM)	Onyx	Nylon
Tensile Modulus (GPa)	D638	1.4	0.94
Tensile Stress at Yield (MPa)	D638	36	31
Tensile Strain at Yield (%)	D638	25	27
Tensile Stress at Break (MPa)	D638	30	54
Tensile Strain at Break (%)	D638	58	260
Flexural Strength (MPa)	D790[1]	81	32
Flexural Modulus (GPa)	D790[1]	2.9	0.84
Heat Deflection Temp (°C)	D648 B	145	49
Izod Impact - notched (J/m)	D256-10 A	330	1000
Density (g/cm^3)	—	1.2	1.1

Dimensions and Construction of Plastic Test Specimens:

- Tensile test specimens: ASTM D638 type IV beams
- Flexural test specimens: 3-pt. Bending, 4.5 in (L) x 0.4 in (W) x 0.12 in (H)
- Heat-deflection temperature at 0.45 MPa, 66 psi (ASTM D648-07 Method B)

All Markforged machines are equipped to print Onyx. Nylon is a specialized material that can only be printed on the Mark Two and X7. Machines that print Onyx cannot also print Nylon due to machine conditioning.

Markforged parts are primarily composed of plastic matrix. Users may add one type of fiber reinforcement in each part, enhancing its material properties.

1. Measured by a method similar to ASTM D790. Thermoplastic-only parts do not break before end of Flexural Test.

FIBER REINFORCEMENT	Test (ASTM)	Carbon	Kevlar®	Fiberglass	HSHT FG
Tensile Strength (MPa)	D3039	700	610	590	600
Tensile Modulus (GPa)	D3039	54	27	21	21
Tensile Strain at Break (%)	D3039	1.5	2.7	3.8	3.9
Flexural Strength (MPa)	D790[1]	470	190	210	420
Flexural Modulus (GPa)	D790[1]	51	26	22	21
Flexural Strain at Break (%)	D790[1]	1.2	2.1	1.1	2.2
Compressive Strength (MPa)	D6641	320	97	140	192
Compressive Modulus (MPa)	D6641	54	28	21	21
Compressive Strain at Break (%)	D6641	0.7	1.5	—	—
Heat Deflection Temp (°C)	D648 B	105	105	105	150
Izod Impact - notched (J/m)	D256-10 A	960	2000	2600	3100
Density (g/cm^3)	—	1.4	1.2	1.5	1.5

Dimensions and Construction of Fiber Composite Test Specimens:

- Test plaques used in these data are fiber reinforced unidirectionally (0° Plies)
- Tensile test specimens: 9.8 in (L) x 0.5 in (H) x 0.048 in (W) (CF composites), 9.8 in (L) x 0.5 in (H) x 0.08 in (W) (GF and Kevlar® composites)
- Compressive test specimens: 5.5 in (L) x 0.5 in (H) x 0.085 in (W) (CF composites), 5.5 in (L) x 0.5 in (H) x 0.12 in (W) (Kevlar® and GF composites)
- Flexural test specimens: 3-pt. Bending, 4.5 in (L) x 0.4 in (W) x 0.12 in (H)
- Heat-deflection temperature at 0.45 MPa, 66 psi (ASTM D648-07 Method B)

Tensile, Compressive, Strain at Break, and Heat Deflection Temperature data were provided by an accredited 3rd party test facility. Flexural data were prepared by Markforged, Inc. The above specifications were met or exceeded.

Markforged tests plaques are uniquely designed to maximize test performance. Fiber test plaques are fully filled with unidirectional fiber and printed without walls. Plastic test plaques are printed with full infill. To learn more about specific testing conditions or to request test parts for internal testing, contact a Markforged representative.

Part and material performance will vary by fiber layout design, part design, specific load conditions, test conditions, build conditions, and the like.

MATERIAL DESCRIPTIONS

COMPOSITES

Markforged

Printing Methods

Plastic Matrix

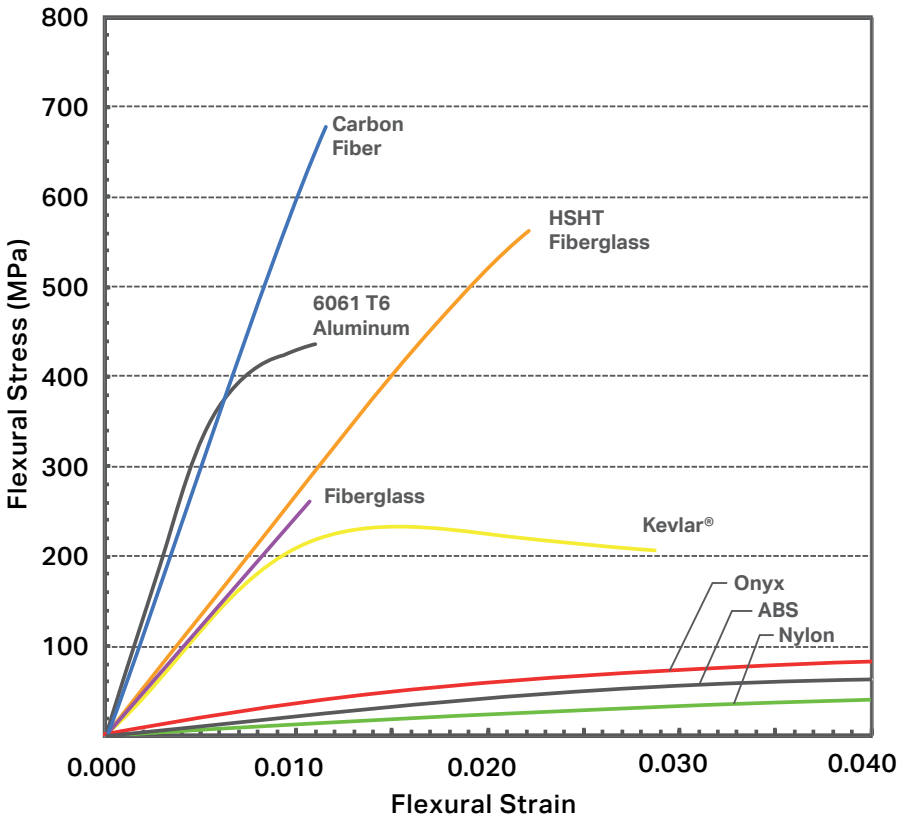
In **Fused Filament Fabrication (FFF)**, the printer heats thermoplastic filament to near melting point and extrudes it through its nozzle, building a plastic matrix layer by layer. Markforged prints all thermoplastics by this method.

Onyx Nylon

Fiber Reinforcement

Continuous Filament Fabrication (CFF) is our unique technology that adds fiber reinforcement to printed parts. Within our thermoplastic matrix, Markforged uses proprietary technology to lay down continuous long-strand fiber. Users can control the layers reinforced, amount, orientation, and type of reinforcing fiber.

Fiberglass Carbon Fiber
Kevlar® HSHT Fiberglass



Materials

Onyx Plastic

Engineering Grade Thermoplastic

Onyx yields stiff, strong, and accurate parts. Already 1.4 times stronger and stiffer than ABS, Onyx can be reinforced with any continuous fiber. Onyx sets the bar for surface finish, chemical resistivity, and heat tolerance.

Flexural Strength	**81 MPa**
Flexural Stiffness	**2.9 GPa**

Fiberglass Fiber

Reinforced Fiber Strength

Fiberglass is our entry level continuous fiber, providing high strength at an accessible price. 2.5 times stronger and eight times stiffer than Onyx, Fiberglass reinforcement results in strong, robust tools.

Flexural Strength	**210 MPa**
Flexural Stiffness	**22 GPa**

Carbon Fiber Fiber

Aluminum Strength. Half the Weight.

Carbon Fiber has the highest strength to weight ratio of our reinforcing fibers. Six times stronger and eighteen times stiffer than Onyx, Carbon Fiber reinforcement is commonly used for parts that replace machined aluminum.

Flexural Strength	**470 MPa**
Flexural Stiffness	**51 GPa**

Nylon Plastic

Tough Flexible Thermoplastic

Nylon parts are flexible, impact-resistant and can be reinforced with any Markforged continuous fiber. The material works best in applications that require more flexibility or low working friction.

Flexural Strength	**32 MPa**
Flexural Stiffness	**0.84 GPa**

Kevlar® Fiber

Lightweight, Durable, and Strong

Kevlar® possesses excellent durability, making it optimal for parts that experience repeated and sudden loading. As stiff as fiberglass and much more ductile, it's best used for end of arm tooling.

Flexural Strength	**190 MPa**
Flexural Stiffness	**26 GPa**

HSHT Fiberglass Fiber

Strength at High Temperatures

High Strength High Temperature (HSHT) Fiberglass exhibits Aluminum strength and high heat tolerance. Five times as strong and seven times as stiff as Onyx, it's best used for parts loaded in high operating temperatures.

Flexural Strength	**420 MPa**
Flexural Stiffness	**21 GPa**