Composites - Material Spec Sheet

Composite Base	Test (ASTM)	Onyx	Onyx FR	Onyx ESD	Nylon
Tensile Modulus (GPa)	D638	2.4	3.0	4.2	1.7
Tensile Stress at Yield (MPa)	D638	40	41	52	51
Tensile Stress at Break (MPa)	D638	37	40	50	36
Tensile Strain at Break (%)	D638	25	18	25	150
Flexural Strength (MPa)	D790[1]	71	71	83	50
Flexural Modulus (GPa)	D790[1]	3.0	3.6	3.7	1.4
Heat Deflection Temp (°C)	D648 B	145	145	138	41
Flame Resistance	UL94	—	V-0[2]	—	—
Izod Impact - notched (J/m)	D256-10 A	330	—	44	110
Surface Resistance (Ω)	ANSI/ESD STM11.11[3]	—	—	10^5 - 10^7	—
Density (g/cm³)	—	1.2	1.2	1.2	1.1

Markforged parts are primarily composed of Composite Base materials. Users may reinforce parts with one type of Continuous Fiber.

Dimensions and construction of test specimens:

- Tensile: ASTM D638 type IV beams
- Flexural: 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)

1. Measured by a method similar to ASTM D790. Composite Base -only parts do not break before end of flexural test.

2. Onyx FR is UL 94 V-0 Blue Card certified down to a thickness of 3mm.

3. Surface resistance measured on multiple part surfaces using recommended print settings by an accredited third party test facility. See Onyx ESD technical data sheet for more details.

Continuous Fiber	Test (ASTM)	Carbon	Kevlar®	Fiberglass	HSHT FG
Tensile Strength (MPa)	D3039	800	610	590	600
Tensile Modulus (GPa)	D3039	60	27	21	21
Tensile Strain at Break (%)	D3039	1.5	2.7	3.8	3.9
Flexural Strength (MPa)	D790[1]	540	240	200	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/cm³)	—	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 FG 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 was prepared by Markforged. Inc. These represent typical values.

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. All customer parts should be tested in accordance to customer's specifications.

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

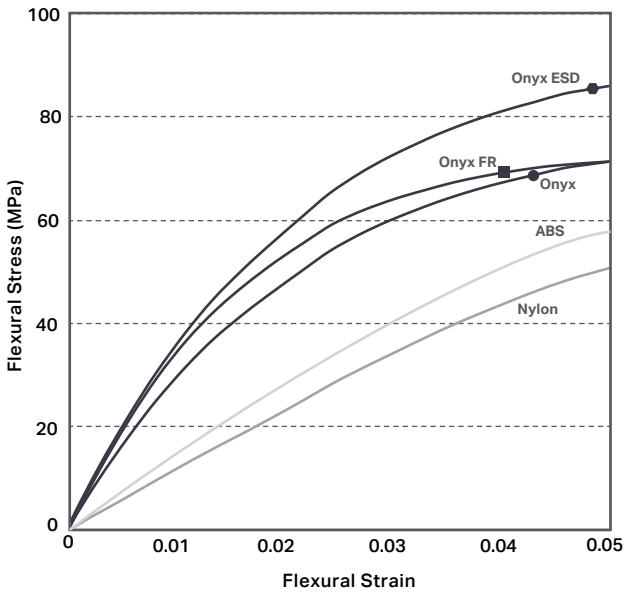
MATERIAL DESCRIPTIONS

Composites

Markforged composite printers are capable of Continuous Fiber Reinforcement (CFR) — a unique process that reinforces FFF parts with high-strength continuous fibers. A CFR capable machine uses two extrusion systems: one that extrudes Composite Base material in a standard FFF process, and a second for long strand continuous fibers that are laid down in-layer, replacing FFF infill.

Composite Base

Markforged Composite Base materials print like conventional FFF thermoplastics. They can be printed by themselves, or reinforced with any of our continuous fibers, including Carbon Fiber, Kevlar, and Fiberglass.



Onyx — Flexural Strength: 71 MPa

Onyx is a micro carbon fiber filled nylon. It's 1.4 times stronger and stiffer than ABS and can be reinforced with any continuous fiber. Onyx sets the bar for surface finish, chemical resistivity, and heat tolerance.

Onyx FR — Flexural Strength: 71 MPa

Onyx FR is a Blue Card certified UL94 V-0 material that possesses similar mechanical properties to Onyx. It's best for applications in which flame retardancy, light weight, and strength are required.

Onyx ESD — Flexural Strength: 83 MPa

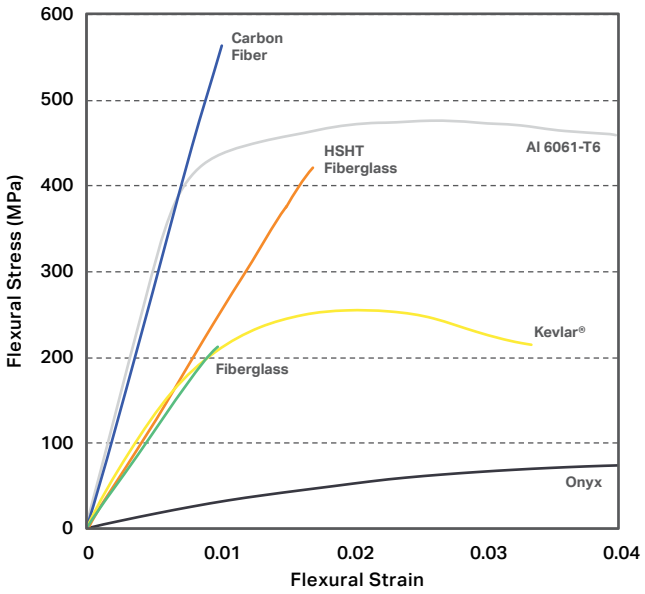
Onyx ESD is a static dissipative safe variant of Onyx — meeting stringent ESD safety requirements while offering excellent strength, stiffness, and surface finish. It's best used in applications that require ESD safe materials.

Nylon — Flexural Strength: 50 MPa

Nylon White parts are smooth, non-abrasive, and easily painted. They can be reinforced with any continuous fiber and work best for non-marring work holding, repeated handling, and cosmetic parts.

Continuous Fiber

Continuous Fibers are laid down on the inside of parts through a second fiber nozzle. They cannot be printed by themselves — instead, they are used to reinforce parts printed out of a composite base material like Onyx.



Carbon Fiber — Flexural Strength: 540 MPa

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.

Fiberglass — Flexural Strength: 200 MPa

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.

Kevlar® — Flexural Strength: 240 MPa

Kevlar® possesses excellent durability, making it optimal for parts that experience repeated and sudden loading. As stiff as fiberglass and much more ductile, it can be used for a wide variety of applications.

HSHT Fiberglass — Flexural Strength: 420 MPa

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.

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ONYX CHEMICAL RESISTIVITY - Datasheet

Material	Onyx	ABS	Delta
Acetone	A	D	+++
Ammonium Carbonate Aq.	A	*	
Ammonium Chloride Aq.	A	*	
Amyl Acetate	A	D	+++
Barlium Chloride Aq.	A	*	
Benzene	A	D	+++
Boric Acid Aq.	A	*	
Camphor	A	*	
Carbon Tetrachloride	A	D	+++
Chrome Alum Aq.	A	*	
Creosote	A	*	
Cyclohexanone	A	*	
Detergents, Organic	A	*	
Dibutylphthalate	A	*	
Diesel Oil	A	*	
Dioxan	A	*	
Ether, Diethyl	A	*	
Ethyl Acetate	A	D	+++
Freon 12 (Arcton 12)	A	*	
Glycerine	A	A	=
Heptane	A	*	
Linseed Oil	A	*	
Lubricating Oils (Petroleum)	A	*	
Magnesium Chloride Aq.	A	*	
Methyl Acetate	A	*	
Methyl Ethyl Ketone	A	D	+++
Mineral Oils	A	*	
Naphthalene	A	D	+++
Nickel Sulphate Aq.	A	*	
Oleic Acid	A	*	
Paraffin	A	*	
Petrol	A	*	
Potassium Bicarb. Aq.	A	*	
Potassium Chloride Aq.	A	A	=
Potassium Ferrocyanide Aq.	A	*	
Propane Gas	A	*	
Salicylic Acid	A	*	
Silicone Fluids	A	D	+++
Silver Nitrate	A	*	
Soap Solutions	A	B	+
Sodium Bicarbonate Aq.	A	*	
Sodium Nitrate Aq.	A	*	
Stearic Acid	A	*	
Styrene (Monomer)	A	*	
Tallow	A	*	
Toluene	A	D	+++
Transformer Oil	A	*	
Triethanolamine	A	*	
Turpentine	A	D	+++
Urea	A	*	
Vaseline	A	B	=+
Vegetable Oils	A	C	++
Vinyl Chloride	A	*	
Water	A	A	
Wax (Molten)	A	C	++
White Spirit	A	*	
Acetaldehyde Aq.	B	D	++

Material (Continued)	Onyx	ABS	Delta
Alcohols, Aliphatic	B	*	
Butanol	B	*	
Butyric Acid Aq.	B	*	
Cyclohexanol	B	*	
Ethylene Dichloride	B	D	++
Ethylene Glycol Aq.	B	*	
Formaldehyde Aq.	B	*	
Formic Acid Aq.	B	*	
Hydrogen Sulphide Aq.	B	*	
Hydroquinone	B	*	
Isopropylalcohol	B	C	+
Lead Acetate Aq.	B	*	
Phthalic Acid Aq.	B	*	
Sodium Acetate Aq.	B	*	
Sulphur Dioxide (Dry Gas)	B	D	++
Tar	B	*	
Trichlorethylene	B	*	
Acetic Acid Aq.	C	*	
Ammonia Gas	C	*	
Anillne	C	*	
Antimony Trichoride Aq.	C	*	
Bleaching Lye	C	C	=
Butyric Acid	C	D	+
Chromic Acid Aq.	C	*	
Citric Acid Aq.	C	B	-
Ferrous Chloride Aq.	C	*	
Hydrofluoric Acid Aq	C	*	
Hydrogen Peroxide Aq.	C	*	
Lactic Acid Aq.	C	*	
Methyl Chloride	C	*	
Nitric Acid Aq.	C	B	-
Oxalic Acid Aq.	C	*	
Ozone	C	*	
Stannic Chloride Aq.	C	*	
Sulphuric Acid Aq.	C	B	
Vinegar	C	A	--
Zinc Chloride Aq.	C	*	
Benzene Sulphonic Acid	D	*	
Bromine Aq.	D	*	
Calcium Hypochlorite	D	*	
Chloral Hydrate	D	*	
Chlorine Aq.	D	*	
Chloroform	D	D	=
Chlorosulphonic Acid Aq.	D	*	
Cresylic Acid	D	*	
Fluorine	D	*	
Hydrobromic Acid Aq.	D	A	---
Hydrogen Peroxide Aq.	D	*	
Iodine (in Pot Iodine) Aq.	D	*	
Nitric Acid Aq.	D	*	
Perchloric Acid Aq.	D	*	
Phenol Aq.	D	*	
Phosphoric Acid Aq.	D	*	
Chlorine Bleach	D	*	
Sulphuric Acid Aq.	D	*	
Sulphurous Acid Aq.	D	*	
Xylene	D	D	=

LEGEND

A - No Attack, possibly slight absorption. Negligible effect on mechanical properties.

B - Slight attack by absorption. Some swelling and a small reduction in mechanical likely.

C - Moderate attack of appreciable absorption. Material will have limited life.

D - Material will decompose or dissolve in a short time.

All specifications approximate and subject to change without notice.

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