

Onyx FR-A and Carbon Fiber FR-A

AEROSPACE-READY MATERIALS



Overview

Onyx FR is a flame-retardant short carbon fiber filled nylon designed for use in applications where parts must resist burning. The material earned a UL Blue Card, and is considered V-0 (self-extinguishing) at thicknesses greater than or equal to 3mm. It can be reinforced with any Continuous Fiber and is compatible with industrial composite 3D printers.

Carbon Fiber FR is a flame-retardant variant of Markforged's unique, ultra-high-strength Continuous Carbon Fiber — when used to reinforce a Composite Base material like Onyx FR, it can yield parts as strong as 6061-T6 Aluminum. It's extremely stiff and strong, and can be precisely laid down in a wide variety of geometries. Programmatically trace curved features, reinforce holes, and mimic unidirectional fiber layups — all within a few clicks.

Onyx FR-A and Carbon Fiber FR-A are purpose-built for the requirements of the aerospace, transportation and automotive industries. FR-A materials establish lot-level material traceability and pass the test suite necessary for qualification under 14 CFR 25.853 for most 3D-printable parts. Onyx FR-A and Carbon Fiber FR-A as printed on the Markforged X7 have been qualified by NCAMP.

For specific inquiries please contact aerospace@markforged.com

Material Performance

The FR-A variants of Onyx and Carbon Fiber are used in a similar manner to their standard counterparts. Carbon Fiber FR-A can enhance the mechanical properties of Onyx FR-A parts. The rule of mixtures can be used to approximate bulk mechanical properties of printed composites. Your results may vary based on a number of factors including environmental conditions, feature geometry, print orientation, and loading conditions.

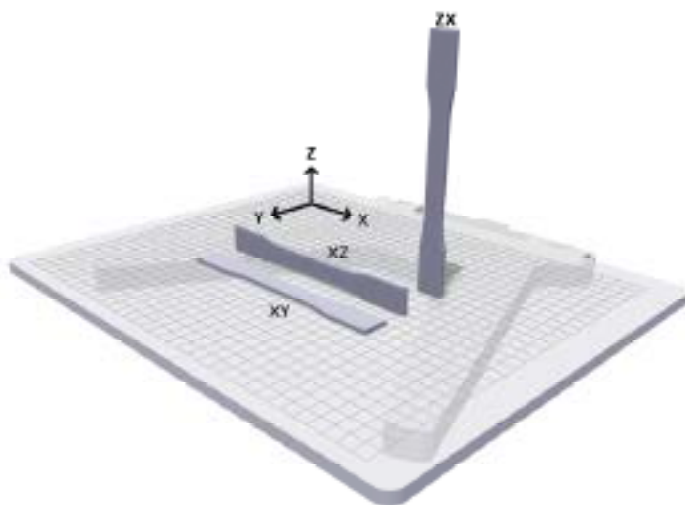
Mechanical Properties

| Property | Unit | Test (ASTM) | Onyx FR-A | CF Test (ASTM) | Carbon Fiber FR-A |
|--------------------------|-------------------|-------------|-----------|----------------|-------------------|
| Tensile Strength | MPa (ksi) | D638 | 40 (5.8) | D3039 | 760 (110.2) |
| Tensile Modulus | GPa (ksi) | D638 | 3 (440) | D3039 | 57 (8267.2) |
| Tensile Strain at Break | % | D638 | 18 | D3039 | 1.6 |
| Flexural Strength | MPa (ksi) | D790 | 71 (10.3) | D790 | 540 (78.3) |
| Flexural Modulus | GPa (ksi) | D790 | 3.6 (520) | D790 | 51 (7396.9) |
| Flexural Strain at Break | % | | — | D790 | 1.6 |
| Izod Impact - notched | J/m (/in) | D256-10 A | — | D256-10 A | 810 (15.2) |
| Density | g/cm ³ | — | 1.2 | — | 1.4 |
| Heat Deflection Temp | deg C (deg F) | D648 B | 145 (293) | D648 B | 105 (221) |
| Mean XY CTE, 25-145 °C | µm/(m·°C) | — | 30 | — | — |

Directional Mechanical Properties of Onyx FR

The mechanical properties of 3D printed materials may vary with print orientation. In tension, most parts are strongest when the print orientation and loading direction are parallel, and weakest when the print orientation and loading direction are perpendicular.

| Property | Print Orientation | Average | St. Dev. |
|-------------------------|-------------------|---------|----------|
| Yield Strength* (MPa) | XY | 46.6 | 0.16 |
| | ZX | 15.7 | 0.9 |
| | XZ | 40.6 | 0.6 |
| Tensile strength (MPa) | XY | 46.7 | 0.3 |
| | ZX | 16.2 | 0.8 |
| | XZ | 40.3 | 1.2 |
| Tensile modulus (GPa) | XY | 3.27 | 0.08 |
| | ZX | 1.05 | 0.08 |
| | XZ | 2.94 | 0.11 |
| Elongation at break (%) | XY | 14.0 | 0.4 |
| | ZX | 3.9 | 0.4 |
| | XZ | 25.5 | 7.6 |



Flame, Smoke, and Toxicity (FST) Performance

Onyx FR-A alone and Onyx FR-A with Carbon Fiber FR-A reinforcement have demonstrated Flammability test performance that passes CFR 25.853 specifications at 3.7mm thickness with the exception of Heat Release. For information on how this limits potential applications see PS-ANM-25.853-01-R2. Smoke test performance passed CFR 25.853 specifications at 3.7mm thickness, but not at 2mm

thickness. Combustion toxicity test performance passed Boeing BSS 7239 Flaming specifications at 2mm thickness. Generally thinner specimens have greater difficulty passing testing. Performance of the thinnest specimens that passed testing (and Heat Release at the thickest tested specimen, which did not pass) are shown below. All samples were printed with solid fill.

| Test Category | Test Detail | Specification | Thickness | Continuous Fiber Loading | Test | Passing Criteria | Test Result | Outcome |
|---------------|----------------------|--|-----------|--------------------------|---|---|--|----------|
| Flammability | Vertical (60 seg.) | FAR 25.853 Appendix F, Part I (a) (1) (i) | 2 mm | None | Burn Time Burn Length Longest Burning | ≤ 15 sec ≤ 6 in ≤ 3 sec | 9 sec 4.1 in None | Pass |
| | | | 2 mm | Full | Burn Time Burn Length Longest Burning | ≤ 15 sec ≤ 6 in ≤ 3 sec | 9 sec 4.3 in None | Pass |
| | Vertical (12 seg.) | FAR 25.853 Appendix F, Part I (a) (1) (ii) | 2 mm | None | Burn Time Burn Length Longest Burning | ≤ 15 sec ≤ 8 in ≤ 5 sec | 2 sec 1.0 in None | Pass |
| | | | 2 mm | Full | Burn Time Burn Length Longest Burning | ≤ 15 sec ≤ 8 in ≤ 5 sec | 0 sec 1.3 in None | Pass |
| | Horizontal (15 seg.) | FAR 25.853 Appendix F, Part I (a) (1) (iv) | 2 mm | None | Avg. Burn Length | ≤ 2.5 in/min | 0 in/min | Pass |
| | | | 2 mm | Full | Avg. Burn Length | ≤ 2.5 in/min | 0 in/min | Pass |
| | Heat release* | FAR 25.853 Appendix F, Part IV | 3,7 mm | None | Avg. Max Avg. 2-min total | ≤ 65 kW/m2 ≤ 65 kW-min./m2 | 196 kW/m2 158 kW-min./m2 | Not pass |
| | | | 3.7 mm | Full | Avg. Max Avg. 2-min total | ≤ 65 kW/m2 ≤ 65 kW-min./m2 | 97 kW/m2 114 kW-min./m2 | Not pass |
| | Smoke | Smoke Density - flaming mode | 3.7 mm | None | Ds | ≤ 200 | 191 | Pass |
| | | | 3.7 mm | Partial** | Ds | ≤ 200 | 139 | Pass |
| | | | 3.7 mm | Full | Ds | ≤ 200 | 115 | Pass |
| Toxicity | Combustion Toxicity | BSS 7239 | 2 mm | None | HCN CO NO / NO2 SO2 HF HCL | ≤ 150 PPM ≤ 3500 PPM ≤ 100 PPM ≤ 100 PPM ≤ 200 PPM ≤ 500 PPM | — / — 351 / 368 20 / 34 7 / 9 <1 / <1 15 / 25 | Pass |
| | | | 2 mm | Full | HCN CO NO / NO2 SO2 HF HCL | ≤ 150 PPM ≤ 3500 PPM ≤ 100 PPM ≤ 100 PPM ≤ 200 PPM ≤ 500 PPM | 35 / 40 81 / 49 5 / 3 0 / 0 <1 / <1 25 / 30 | Pass |

* Per PS-ANM-25.853-01-R2, the Heat Release test is not required for most interior-facing parts printable on the X7, as they have exposed-surface area below the specified threshold for cabin components.

**Partial sample produced as a 2-layer sandwich panel

Printer & Material Compatibility

Onyx FR-A

Available for use on the X7, FX10, and FX20.

Can be reinforced with available continuous fibers.

Carbon Fiber FR-A

Available for use on the X7, FX10, and FX20.

Only compatible as a reinforcement for Onyx FR-A.

| Printer | Composite Base | Continuous Fiber |
|---------|----------------|--|
| X7 | Onyx FR-A | Carbon Fiber FR-A Carbon Fiber HSHF Fiberglass Kevlar Fiberglass No reinforcement |
| FX10 | Onyx FR-A | Carbon Fiber FR-A Carbon Fiber No reinforcement |
| FX20 | Onyx FR-A | Carbon Fiber FR-A Carbon Fiber Fiberglass No reinforcement |

Additional Data

Onyx FR-A and Carbon Fiber FR-A, as printed on the X7, have been qualified by NCAMP. The following additional test results are available in the [NCAMP report](#):

Expanded directional mechanical data

Environmental mechanical data

Glass transition temperature

Coefficient of thermal expansion (CTE)

UV Exposure

Fluid sensitivity to common aerospace fluids including fuels, lubricants, and cleaning agents



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. This representative data were tested, measured, or calculated using standard methods and are subject to change without notice. Markforged makes no warranties of any kind, express or implied, including, but not limited to, the warranties of merchantability, fitness for a particular use, or warranty against patent infringement; and assumes no liability in connection with the use of this information. The data listed here should not be used to establish design, quality control, or specification limits, and are not intended to substitute for your own testing to determine suitability for your particular application. Nothing in this sheet is to be construed as a license to operate under or a recommendation to infringe upon any intellectual property right.