

# Vega™

## CARBON FIBER FILLED PEKK MATERIAL

Vega is an ultra high-performance carbon fiber filled PEKK for 3D printing critical aerospace parts on the FX20. Formulated by Markforged engineers and material scientists, it exhibits a smooth matte black surface finish that is excellent for production parts. Vega can be reinforced with continuous fiber to achieve aluminum strength for aerospace components.

Carbon Fiber HT and Carbon Fiber HT-A are specialized variants of Markforged's continuous Carbon Fiber designed for use with Vega and ULTEM™ 9085 Filament<sup>1</sup>. Capable of yielding aluminum strength parts, they can be precisely laid down in a wide variety of geometries.

### Features and benefits

High heat and FST resistance

Chemical and solvent resistance

Low outgassing

Matte surface finish

High strength with CF-HT reinforcement



| Physical Properties            | Unit              | Test (ASTM) | Vega<br>XZ Orientation    | Test  | Carbon Fiber HT (CFR) <sup>2</sup> | Carbon Fiber HT-A (CFR) <sup>2 3</sup> |
|--------------------------------|-------------------|-------------|---------------------------|-------|------------------------------------|--|
| Tensile Strength               | MPa (ksi)         | D638        | 87.6 ± 3.0 (12.7 ± 0.5)   | D3039 | 800 (116)                          | 800 (116)                              |
| Tensile Modulus                | GPa (ksi)         | D638        | 5.2 ± 0.2 (0.8 ± 0.03)    | D3039 | 69 (10,005)                        | 69 (10,005)                            |
| Elongation at Break            | %                 | D638        | 3.0 ± 0.2                 | D3039 | 1.6                                | 1.6                                    |
| Flexural Strength              | MPa (ksi)         | D790        | 140.2 ± 8.4 (20.3 ± 1.2)  | D790  | 439.5 (63.7)                       | 529.7 (76.8)                           |
| Flexural Modulus               | GPa (ksi)         | D790        | 4.7 ± 0.3 (678.3 ± 0.04)  | D790  | 50.3 (7,291.1)                     | 53.3 (7,730.5)                         |
| Flexural Extension at Break    | %                 | D790        | 5.2 ± 0.5                 | D790  | 1.0                                | 1.1                                    |
| Compressive Strength           | MPa               | D695        | 221.3 ± 35.9 (32.1 ± 5.2) | D695  | 300 (43.5)                         | 300 (43.5)                             |
| Compressive Modulus            | GPa               | D695        | 4.1 ± 0.3 ( 591.0 ± 37.0) | D695  | 59 (8,557)                         | 59 (8,557)                             |
| Notched Izod Impact Resistance | J/m               | D256        | 47.9 ± 3.8                | D256  | 810 (15.2)                         | 810 (15.2)                             |
| Density                        | g/cm <sup>3</sup> | –           | 1.27 ± 0.03               | –     | 1.20                               | 1.20                                   |
| HDT (1.8 MPa)                  | deg C (deg F)     | D648        | 150.8 (303.4)             | –     | 190 (374)                          | 190 (374)                              |
| HDT (0.45 MPa)                 | deg C (Deg F)     | D648        | 165.1 (329.2)             | –     | 190 (374)                          | 190 (374)                              |

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<sup>1</sup> The "ULTEM™" and 9085 trademarks are used under license from SABIC, its affiliates or subsidiaries.

<sup>2</sup> CF-HT and CF-HT-A values are derived from pure fiber test specimens. Actual part strength will depend on the amount and pathing of fiber in the part.

<sup>3</sup> CF-HT-A is recommend for material and system qualification.

## Outgassing

Vega exhibits low outgassing, ensuring suitability for critical aerospace applications.

| Property   | Test (ASTM) | TML (%) | CVCM (%) | WVR (%) |
|------------|-------------|---------|----------|---------|
| Outgassing | E595-15     | 0.47    | <0.01    | 0.21    |

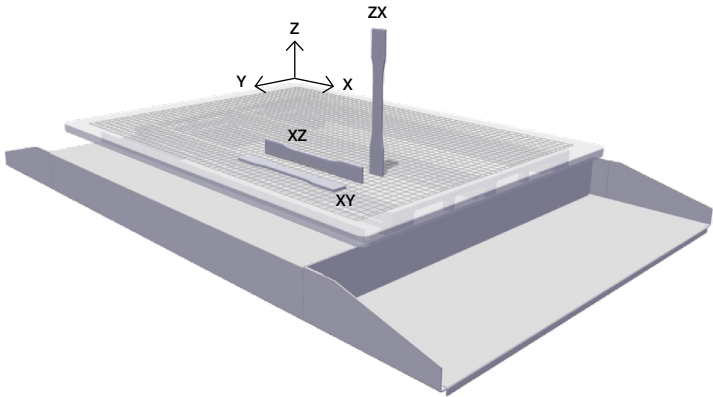
## Chemical Resistance

| Property                | Vega |
|-------------------------|------|
| 37% Hydrochloric Acid   | A    |
| 80% Phosphoric Acid     | A    |
| 49% Hydrogen Fluoride   | A    |
| 50% Potassium Hydroxide | A    |
| 50% Hydrogen Peroxide   | A    |
| Ethanol                 | A    |
| Jet A                   | A    |
| Skydrol                 | A    |
| Toluene                 | B    |
| MEK                     | B    |
| Trichlorethane          | C    |
| Dichloromethane         | C    |

**Legend**  
A - Little / no effect  
B - Small / moderate effect  
C - Significant effect

## Directional Mechanical Properties of Vega

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 <sup>4</sup>   | Print orientation | Average    |
|-------------------------|-------------------|------------|
| Tensile strength (MPa)  | XY                | 65.2 ± 3.0 |
|                         | XZ                | 87.6 ± 3.0 |
|                         | ZX                | 47.5 ± 3.3 |
| Tensile modulus (GPa)   | XY                | 4.0 ± 0.1  |
|                         | XZ                | 5.2 ± 0.2  |
|                         | ZX                | 3.3 ± 0.2  |
| Elongation at break (%) | XY                | 3.9 ± 0.4  |
|                         | XZ                | 3.0 ± 0.2  |
|                         | ZX                | 5.2 ± 0.5  |

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<sup>4</sup> XY and XZ specimens were printed with default solid fill settings. ZX specimens were printed with solid fill settings with 6 walls and 4 floors.

## Flame, Smoke, and Toxicity (FST) Performance

Vega alone and with Carbon Fiber reinforcement have demonstrated Flammability test performance that passes CFR 25.853 specifications at 2mm thickness. For information on how this limits potential applications see PS-ANM-25.853-01-R2. Smoke test performance passed CFR 25.853 specifications 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 are shown below.

| 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                                 | ≤ 15 sec  | 0 sec  | Pass    |
|               |                                  |  |           |                          | Burn Length                               | ≤ 6 in  | 3.3 in   |         |
|               |                                  |  |           |                          | Longest Burning                           | ≤ 3 sec   | None   |         |
|               |                                  |  | 2 mm      | Full                     | Burn Time                                 | ≤ 15 sec  | 0 sec  | Pass    |
|               |                                  |  |           |                          | Burn Length                               | ≤ 6 in  | 3.1 in   |         |
|               |                                  |  |           |                          | Longest Burning                           | ≤ 3 sec   | None   |         |
|               | Vertical (12 seg.)               | FAR 25.853 Appendix F, Part I (a) (1) (ii) | 2 mm      | None                     | Burn Time                                 | ≤ 15 sec  | 2 sec  | Pass    |
|               |                                  |  |           |                          | Burn Length                               | ≤ 8 in  | 0.9 in   |         |
|               |                                  |  |           |                          | Longest Burning                           | ≤ 5 sec   | None   |         |
|               |                                  |  | 2.0 mm    | Full                     | Burn Time                                 | ≤ 15 sec  | 0 sec  | Pass    |
|               |                                  |  |           |                          | Burn Length                               | ≤ 8 in  | 0.4 in   |         |
|               |                                  |  |           |                          | Longest Burning                           | ≤ 5 sec   | None   |         |
|               | Horizontal (15 seg.)             | FAR 25.853 Appendix F, Part I (a) (1) (iv) | 2.0 mm    | None                     | Avg. Burn Length                          | ≤ 2.5 in/min  | 0 in/min   | Pass    |
|               |                                  |  | 2.0 mm    | Full                     | Avg. Burn Length                          | ≤ 2.5 in/min  | 0 in/min   | Pass    |
|               | Heat release*                    | FAR 25.853 Appendix F, Part IV             | 2.0 mm    | None                     | Avg. Max<br>Avg. 2-min total              | ≤ 65 kW/m2<br>≤ 65 kW-min./m2   | 40.4 kW/m2<br>6.9 kW-min./m2                             | Pass    |
|               |                                  |  | 2.0 mm    | Full                     | Avg. Max<br>Avg. 2-min total              | ≤ 65 kW/m2<br>≤ 65 kW-min./m2   | 34.1 kW/m2<br>9.3 kW-min./m2                             | Pass    |
| Smoke         | Smoke Density - Flaming Mode     | BSS 7238                                   | 2.0 mm    | None                     | Ds Max                                    | ≤ 200   | 1  | Pass    |
|               | Smoke Density - Non Flaming Mode | BSS 7238                                   | 2.0 mm    | Full                     | Ds Max                                    | ≤ 200   | 0  | Pass    |
| Toxicity      | Toxicity Flaming                 | BSS 7239                                   | 2.0 mm    | None                     | HCN<br>CO<br>NO / NO2<br>SO2<br>HF<br>HCL | ≤ 150 PPM<br>≤ 3500 PPM<br>≤ 100 PPM<br>≤ 100 PPM<br>≤ 200 PPM<br>≤ 500 PPM | <1 / <1<br>29 / 30<br>1/1<br>0 / 0<br><1/<1<br><1/<1     | Pass    |
|               |                                  |  |           | Full                     | HCN<br>CO<br>NO / NO2<br>SO2<br>HF<br>HCL | ≤ 150 PPM<br>≤ 3500 PPM<br>≤ 100 PPM<br>≤ 100 PPM<br>≤ 200 PPM<br>≤ 500 PPM | <1/<1<br>39/26<br>3 / 2<br>0 / 0<br><1 / <1<br><1 / <1   | Pass    |
|               | Toxicity Non Flaming             | BSS 7239                                   | 2.0 mm    | None                     | HCN<br>CO<br>NO / NO2<br>SO2<br>HF<br>HCL | ≤ 150 PPM<br>≤ 3500 PPM<br>≤ 100 PPM<br>≤ 100 PPM<br>≤ 200 PPM<br>≤ 500 PPM | <1 / <1<br>2 / 3<br>0 / 1<br>0 / 0<br><1 / <1<br><1 / <1 | Pass    |
|               |                                  |  |           | Full                     | HCN<br>CO<br>NO / NO2<br>SO2<br>HF<br>HCL | ≤ 150 PPM<br>≤ 3500 PPM<br>≤ 100 PPM<br>≤ 100 PPM<br>≤ 200 PPM<br>≤ 500 PPM | <1 / <1<br><1 / 6<br>1/1<br>0 / 0<br><1/<1<br><1/<1      | 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

Full fiber specimens are produced using the striped fiber configuration with the maximum fiber usage.

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