
# LaserForm® Ti Gr23 (A)

**Titanium alloy fine-tuned for use with ProX® DMP 320 and DMP 350 metal printers. Metal powder producing technical and medical parts with a combination of high specific strength and excellent biocompatibility. LaserForm Ti Gr23 (A) is ELI (Extra Low Interstitial) grade with lower iron, carbon, and oxygen content and is known for higher purity than LaserForm Ti Gr5 (A) resulting in improved ductility and fracture toughness.**

LaserForm Ti Gr23 (A) is formulated and fine-tuned specifically for 3D Systems' ProX DMP 320 and DMP 350 metal 3D printers to deliver highest part quality and best part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging production parts year over year. Based on over 1000 test samples the below listed part quality data and mechanical properties give you high planning security. And for a 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable process results.

## Material Description

This titanium alloy is commonly used in aerospace and medical applications because of its high strength, low weight and excellent biocompatibility. The essential difference between Ti6Al4V ELI (grade 23) and Ti6Al4V (grade 5) is the reduction of oxygen content to 0.13% (maximum) in grade 23. This confers improved ductility and fracture toughness, with some reduction in strength.

These benefits make LaserForm Ti Gr23 (A) the most used medical and aerospace titanium grade. It can be used in biomedical applications such as surgical implants, orthodontic appliances or in-joint replacements due to its biocompatibility, good fatigue strength and low modulus.

## Classification

Parts built with LaserForm Ti Gr23 (A) Alloy have a chemical composition that complies with ASTM F3001, ASTM F3302, ISO 5832-3, ASTM F136 and ASTM B348 standards.

## Mechanical Properties [1,2,3]

| MEASUREMENT | CONDITION | METRIC | | | U.S. | | |
|---|---|---|---|---|---|---|---|
| | | AFTER STRESS RELIEF 1 | AFTER STRESS RELIEF 2 | AFTER HIP | AFTER STRESS RELIEF 1 | AFTER STRESS RELIEF 2 | AFTER HIP |
| Youngs modulus (GPa \| ksi)<br>Horizontal direction — XY<br>Vertical direction — Z | ASTM E1876 | <br>119 ± 3<br>120 ± 1 | <br>119 ± 3<br>120 ± 1 | <br>122 ± 2<br>NA | <br>17300 ± 730<br>17400 ± 300 | <br>17300 ± 730<br>17400 ± 300 | <br>17700 ± 300<br>NA |
| Ultimate Strength (MPa \| ksi) | ASTM E8M | | | | | | |
| Horizontal direction — XY<br>Vertical direction — Z | | 1160 ± 20<br>1170 ± 50 | 1070 ± 30<br>1070 ± 30 | 980 ± 50<br>980 ± 70 | 168 ± 3<br>170 ± 7 | 155 ± 4<br>155 ± 4 | 142 ± 7<br>142 ± 10 |
| Yield strength Rp0.2% (MPa \| ksi) | ASTM E8M | | | | | | |
| Horizontal direction — XY<br>Vertical direction — Z | | 1060 ± 30<br>1100 ± 60 | 970 ± 30<br>1000 ± 60 | 890 ± 50<br>890 ± 90 | 154 ± 4<br>160 ± 9 | 141 ± 4<br>145 ± 9 | 129 ± 7<br>129 ± 13 |
| Plastic elongation (%) | ASTM E8M | | | | | | |
| Horizontal direction — XY<br>Vertical direction — Z | | 10 ± 2<br>10 ± 3 | 13 ± 2<br>13 ± 3 | 14 ± 2<br>14 ± 2 | 10 ± 2<br>10 ± 3 | 13 ± 2<br>13 ± 3 | 14 ± 2<br>14 ± 2 |
| Reduction of area (%) | ASTM E8M | | | | | | |
| Horizontal direction — XY<br>Vertical direction — Z | | 35 ± 10<br>40 ± 10 | 45 ± 10<br>45 ± 15 | 45 ± 5<br>45 ± 5 | 35 ± 10<br>40 ± 10 | 45 ± 10<br>45 ± 15 | 45 ± 5<br>45 ± 5 |
| Hardness, Rockwell C | ASTM E18 | 37 ± 2 | 37 ± 4 | 34 ± 1 | 37 ± 2 | 37 ± 4 | 34 ± 1 |
| Fatigue[4,5] (MPa \| ksi) | ASTM E466 | NA | typical 637 | NA | NA | typical 92 | NA |

## Thermal Properties

| MEASUREMENT | CONDITION | METRIC | U.S. |
|---|---|---|---|
| Thermal conductivity[6] (W/(m.K) \| Btu in/(h.ft.°F)) | At 20 °C/ 68 °F | 4.2 ± 0.1 | 29 ± 1 |
| Coefficient of thermal expansion[7] (µm/(m.°C) \| µ inch/(inch.°F)) | In the range of 20 to 600 °C | 8.6 | 4.8 |
| Melting range[7] (°C \| °F) | | 1692-1698 | 3046-3056 |

[1] Parts manufactured with standard parameters on a ProX DMP 320, Config A
[2] Values based on average and double standard deviation
[3] Surface condition of test samples: Horizontal samples (XY) tested in machined surface condition only, vertical (Z) tested in as-printed and machined surface condition
[4] Force-controlled axial fatigue testing (R=0.1). Endurance limit at 5 x $10^6$ cycles Fatigue samples with machined surface
[5] Results are based on limited sample size, not statistically representative
[6] Thermal conductivity values are calculated by the Wiedemann-Franz law using the respective electrical resistivity values
[7] Values based on literature

## Electrical Properties

| MEASUREMENT | CONDITION | METRIC | U.S. |
|---|---|---|---|
| Electrical conductivity[1,2] ($10^5$ S/m) | ASTM B193 at 20°C / 68°F | 5.9 ± 0.1 | 5.9 ± 0.1 |

## Physical Properties

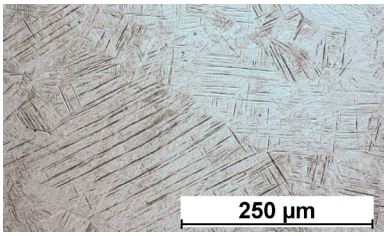
| MEASUREMENT | CONDITION | METRIC | U.S. |
|---|---|---|---|
| | | AS BUILT | AS BUILT |
| Density — Relative, based on pixel count[3,4] (%) | Optical method | > 99.6 typical 99.8 | > 99.6 typical 99.8 |
| Density — Absolute theoretical[5] ($g/cm^3$ \| $lb/in^3$) | | 4.42 | 0.16 |

## Surface Quality[6,7,8]

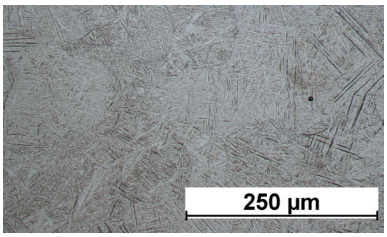
| MEASUREMENT | CONDITION | METRIC | U.S. |
|---|---|---|---|
| | | SANDBLASTED | SANDBLASTED |
| Surface Roughness $R_a$ | ISO 25178 | | |
| Layer thickness 30µm and 60µm<br>Top surface[9] (µm \| µin)<br>Vertical side surface[10] (µm \| µin) | | typical 3-8<br>typical 5-7 | typical 120-320<br>typical 200-280 |
| Layer thickness 90µm<br>Top surface[9] (µm \| µin)<br>Vertical side surface[10] (µm \| µin) | | typical 13-19<br>typical 6-12 | typical 500-750<br>typical 240-480 |

## Chemical Composition

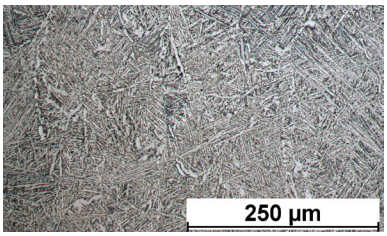
| ELEMENT | % OF WEIGHT |
|---|---|
| Ti | Bal. |
| N | ≤0.03 |
| C | ≤0.08 |
| H | ≤0.012 |
| Fe | ≤0.25 |
| O | ≤0.13 |
| Al | 5.5 - 6.5 |
| V | 3.5 - 4.5 |
| Y | ≤0.005 |
| Residuals (each) | ≤0.1 |
| Residuals (total) | ≤0.4 |



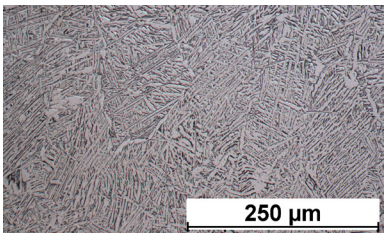
Microstructure as built



Microstructure after stress relief 1



Microstructure after stress relief 2



Microstructure after HIP

[1] Electrical resistivity measurements are based on four point contact method according to ASTM B193
[2] Results are based on limited sample size, not statistically representative
[3] Minimum value based on 95% confidence interval. Tested on typical density test shapes
[4] May deviate depending on specific part geometry
[5] Values based on literature
[6] Parts manufactured with standard parameters on a ProX DMP 320, Config A
[7] Values based on average and double standard deviation
[8] Sand blasting performed with zirconia blasting medium at 5 bar
[9] Top surface measurements along the 2 perpendicular axes of the reference square geometry
[10] Vertical side surface measurement along the building direction

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