LaserForm Ti Gr23 (A)

Titanium alloy fine-tuned for use with DMP Flex 100, ProX® DMP 320, DMP Flex 350, DMP Factory 350 and DMP Factory 500 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' DMP Flex 100, ProX DMP 320, DMP Flex 350, DMP Factory 350 and DMP Factory 500 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 more than 1,000,000 challenging production parts year over year. Based on a multitude of test samples, the properties listed below provide high confidence to the user in terms of job-to-job and machine-to-machine repeatability. Using the LaserForm material enables the user to experience consistent and reliable part quality.

Material Description

This titanium alloy is commonly used in aerospace and medical applications because of its high strength, low density, 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 TiGr23 (A) the most used titanium grade for medical and aerospace applications. It can be used in biomedical applications such as surgical implants, orthodontic appliances or in-joint replacements, as well as in aerospace applications such as lightweight brackets, engine rotor/stator parts or heat exchangers.

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

PROX DMP 320, DMP FLEX 350, DMP FACTORY 350 - LT 30, 60, 90[1, 2, 3, 4, 6]	TEST METHOD	METRIC		U.S.	
		SR[5]	HIP	SR[5]	HIP
Ultimate Tensile Strength (MPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E8M	 1070 ± 30 1070 ± 30	 980 ± 50 980 ± 70	 155 ± 4 155 ± 4	 142 ± 7 142 ± 10
Yield strength Rp 0.2% (MPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E8M	 970 ± 30 1000 ± 60	 890 ± 50 890 ± 90	 141 ± 4 145 ± 9	 129 ± 7 129 ± 13
Plastic elongation (%) Horizontal direction — XY Vertical direction — Z	ASTM E8M	 13 ± 2 13 ± 3	 14 ± 2 14 ± 2	 13 ± 2 13 ± 3	 14 ± 2 14 ± 2
Reduction of area (%) Horizontal direction — XY Vertical direction — Z	ASTM E8M	 45 ± 15 45 ± 15	 45 ± 5 45 ± 5	 45 ± 15 45 ± 15	 45 ± 5 45 ± 5
Fatigue (MPa | ksi)	ASTM E466	Typical 640	-	Typical 92	-

DMP FACTORY 500 - LT 60[2, 6, 7, 8]	TEST METHOD	METRIC		U.S.	
		NHT	SR	NHT	SR
Ultimate Tensile Strength (MPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E8	 1310 ± 20 1290 ± 40	 1060 ± 15 1060 ± 25	 190 ± 3 187 ± 6	 154 ± 2 154 ± 4
Yield strength Rp 0.2% (MPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E8	 1150 ± 20 1150 +30/-55	 960 ± 15 950 ± 30	 167 ± 3 167 +4/-8	 139 ± 2 138 ± 4
Plastic elongation (%) Horizontal direction — XY Vertical direction — Z	ASTM E8	 9 ± 3 11 ± 2	 17 ± 2 18 ± 3	 9 ± 3 11 ± 2	 17 ± 2 18 ± 3
Reduction of area (%) Horizontal direction — XY Vertical direction — Z	ASTM E8	 23 ± 11 32 ± 4	 49 ± 5 52 ± 4	 23 ± 11 32 ± 4	 49 ± 5 52 ± 4

[1] Parts manufactured with standard parameters on a ProX DMP 320, DMP Flex and Factory 350, Config A
[2] Values based on average and 95% tolerance interval with 95% confidence
[3] Tested according to ASTM E8M using round tensile test specimen type 4
[4] Force-controlled axial fatigue testing (R=0.1). Endurance limit at 5 x10^6 cycles. Fatigue samples with machined surface. Values based on limited samples, for information only
[5] Parts manufactured using layer thickness 30 µm and 60 µm only
[6] NHT: Non-heat treated condition; SR: Stress-relieved condition; HIP: Hot isostatically pressed condition
[7] Tested according to ASTM E8 using round tensile test specimen type 4
[8] Parts manufactured with standard parameters on a DMP Factory 500, using layer thickness 60 µm (LT60)

Mechanical Properties

DMP FLEX 100 - LT30[3, 6, 9, 10]	TEST METHOD	METRIC			U.S.		
		NHT	SR	HIP	NHT	SR	HIP
Ultimate strength (MPa | ksi) Horizontal direction - XY Vertical direction - Z	ASTM E8M	 1310 ± 150 1280 ± 70	 1060 ± 60 1040 ± 30	 1020 ± 60 1020 ± 60	 190 ± 22 186 ± 10	 154 ± 9 151 ± 4	 148 ± 9 148 ± 9
Yield strength Rp 0.2% (MPa | ksi) Horizontal direction - XY Vertical direction - Z	ASTM E8M	 1130 ± 140 1070 ± 70	 960 ± 40 930 ± 40	 930 ± 60 930 ± 60	 164 ± 20 155 ± 10	 139 ± 6 135 ± 6	 135 ± 9 135 ± 9
Plastic elongation (%) Horizontal direction - XY Vertical direction - Z	ASTM E8M	 8 ± 2 8 ± 2	 12 ± 4 14 ± 4	 14 ± 4 14 ± 4	 8 ± 2 8 ± 2	 12 ± 4 14 ± 4	 14 ± 4 14 ± 4
Reduction of area (%) Horizontal direction - XY Vertical direction - Z	ASTM E8M	 35 ± 20 35 ± 10	 50 ± 10 50 ± 10	 40 ± 10 40 ± 10	 35 ± 20 35 ± 10	 50 ± 10 50 ± 10	 40 ± 10 40 ± 10

Density

MEASUREMENT	TEST METHOD	METRIC	U.S.
Theoretical density[11] (g/cm³ | lb/in³)	Value from literature	4.42	0.16
DMP Flex 100			
Relative density (%), layer thickness 30 µm[9, 12, 13]	Optical method (pixel count)	≥ 99.4 Typical 99.9	≥ 99.4 Typical 99.9
ProX DMP 320, DMP Flex 350, DMP Factory 350, DMP Factory 500			
Relative density (%), layer thickness 30 µm[1, 12, 13]	Optical method (pixel count)	≥ 99.6 Typical 99.8	≥ 99.6 Typical 99.8
Relative density (%), layer thickness 60 µm[1, 8, 12, 13]	Optical method (pixel count)	≥ 99.6 Typical 99.8	≥ 99.6 Typical 99.8

Surface Roughness R_a

MEASUREMENT[12, 13, 15, 16]	TEST METHOD	METRIC	U.S.
DMP Flex 100[9, 14]			
Top surface (µm | µin) Vertical side surface (µm | µin) Layer thickness 30 µm	NF EN ISO 4288	Typically, around 6 Typically, around 9	Typically, around 236 Typically, around 354
ProX DMP 320, DMP Flex 350, DMP Factory 350, DMP Factory 500[17]			
Vertical side surface (µm | µin)[1] Layer thickness 30 µm	ISO 25178	Typically, around 7	Typically, around 276
Vertical side surface (µm | µin)[1, 8] Layer thickness 60 µm	ISO 25178	Typically, around 9	Typically, around 354

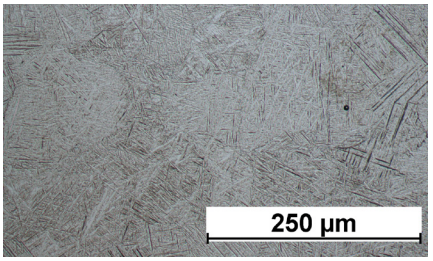
Electrical and Thermal Properties

MEASUREMENT	CONDITION	METRIC	U.S.
Electrical conductivity[18] ((S/m) [x10^5])	Four point contact ASTM B193 at 20°C | 68°F	5.9 ± 0.1	5.9 ± 0.1
Thermal conductivity[11] (W/(m.K) | BTU inch/(hr.ft^2.°F))	at 20°C | 68 °F	6.70	46.5
Coefficient of thermal expansion[11] (µm/(m.°C) | µ inch/(inch.°F))	In the range of 20 to 100 °C	8.6	4.8
Melting range[11] (°C | °F)		1604 - 1660	2919 - 3020

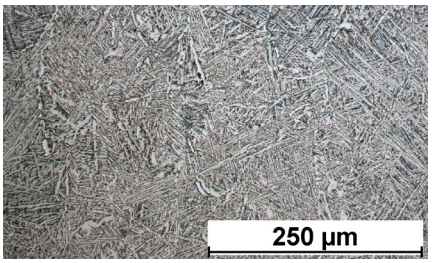
[9] Parts manufactured with standard parameters on a DMP Flex 100, using layer thickness 30 µm (LT30)
[10] Values based on average and double standard deviation
[11] Values based on literature
[12] May deviate depending on specific part geometry
[13] Minimum value based on 95% tolerance interval with 95% confidence. Tested on typical density test shapes
[14] Results obtained in as-printed condition
[15] Surface measurements performed on the top surface plane, which is perpendicular to the building direction
[16] Vertical side surface measurement along the building direction
[17] Surface treatment performed with zirconia blasting medium at 5 bar
[18] Results are based on limited sample size printed on ProX DMP 320, not statistically representative

Chemical Composition

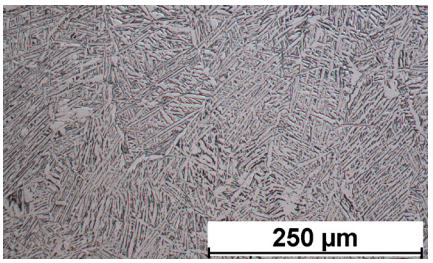
ELEMENT	% OF WEIGHT
Ti	Bal.
N	≤ 0.03
C	≤ 0.08
H	≤ 0.012
Fe	≤ 0.25
O	≤ 0.13
Al	5.50 - 6.50
V	3.50 - 4.50
Y	≤ 0.005
Other (each)	≤ 0.10
Other (total)	≤ 0.40



Microstructure without heat treatment (NHT)



Microstructure after stress relief (SR)



Microstructure after hot isostatic pressing (HIP)

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