22 Ti 24 Cr 26 Fe 27 Co 28 Ni 29 Cu 13 Al

X Line 2000R Titanium Ti-64 Grade 23

Parameter for GE Additive's Concept Laser X Line 2000R

Data in this material datasheet represents material built with 60 µm layer thickness and in an argon atmosphere on a Concept Laser X Line 2000R and requires build plate heating. Values listed are typical.

Titanium

In general, Titanium (Ti) and its alloys have been used extensively in many industries due to their low density, high corrosion resistance and oxidation resistance. Titanium alloys are used in additive manufacturing to produce a wide range of industrial components, including blades, fasteners, rings, discs, hubs and vessels. Titanium alloys are also used to produce high-performance race engine parts like gearboxes and connecting rods.

X Line 2000R Ti-64 Grade 23

The Ti-64 Grade 23 parameters for the Concept Laser X Line 2000R are developed leveraging the performance of the previous X Line generations. The balanced parameters deliver a good balance between surface quality needs and productivity. Furthermore, the parameters offer a very good density leading to high strength and elongation. Moreover, the mechanical properties succeed the limits specified in ASTM F3001 for additive manufactured parts. A large variety of heat treatments have been evaluated, in order to offer the best solution depending on the mechanical properties' requirements.

X Line 2000R Titanium Ti-64 Grade 23

With an appropriate approval* Ti-64 Grade 23 can be used for aerospace and other industrial applications.

Data in this material datasheet represents material built with 60 µm layer thickness and in an argon atmosphere on a Concept Laser X Line 2000R and requires build plate heating. Values listed are typical.

POWDER CHEMISTRY

Ti-64 Grade 23 powder chemical composition according to ASTM F136-02a (ELI Grade 23)/ ASTM F3001. For additional information on Ti-64 Grade 23 powder, visit https://www.advancedpowders.com/powders/titanium/ti-6al-4v-23.

MACHINE CONFIGURATION

- Concept Laser X Line 2000R
- Argon gas
- Carbon brush

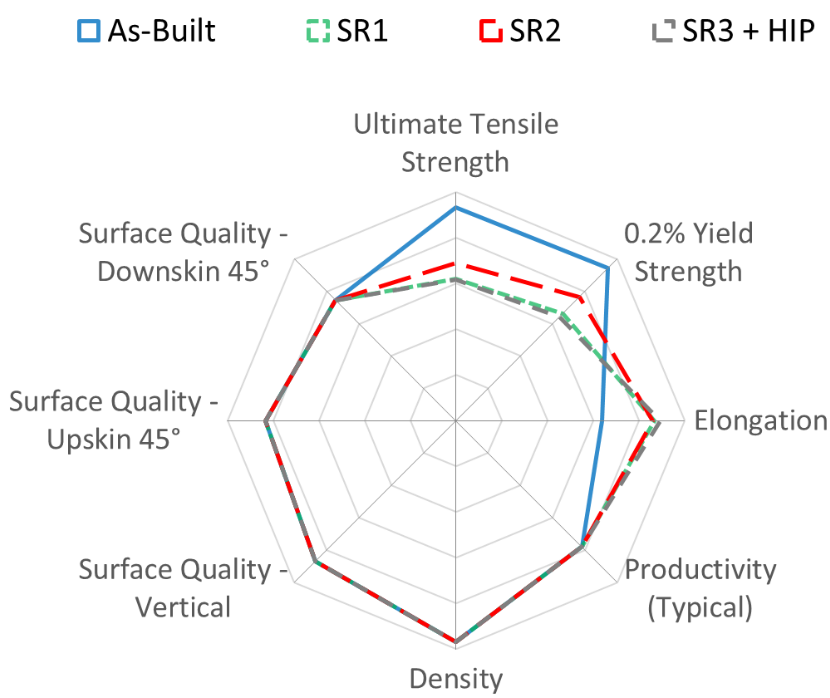
AVAILABLE PARAMETERS

- **Balanced Parameter 104/255** 60 µm layer thickness, argon gas, carbon brush

THERMAL STATES

1. As-Built
2. Stress Relief (SR1)
SR1: 900°C, 1 hour in argon, cooling in argon atmosphere
3. Stress Relief (SR2)
SR2: 840°C, 2 hours in argon, cooling in argon atmosphere
4. Stress Relief + HIP (SR3 + HIP)
SR3: 730°C, 2 hours in argon, cooling in argon atmosphere
+ HIP: 920°C, 2 hours, 100 MPa

THERMAL STATE COMPARISON



Spider Plot is generated by normalizing typical material data (containing both horizontal and vertical data) against a range defined for each material family. For **Ti-64**, the ranges are as follows: UTS: 600-1250 MPa, 0.2%YS: 500-1100 MPa, Elongation: 0-20 %, Density: 99-100 %, Productivity: 5-30 cm³/h, Surface Quality (all): 50-5 µm

TYPICAL BUILD RATE

	(cm³/h)
Typical build rate[1] w/coating	17.9
Theoretical melting rate[2] bulk per Laser	31.1

[1]Using standard Factory Acceptance Test layout and 2 lasers
[2]Calculated (layer thickness x scan velocity x hatch distance)

PHYSICAL DATA AT ROOM TEMPERATURE

	Surface Roughness Ra** - Overhang (µm)		
	45°	60°	75°
Upskin	17	13	10
Downskin	17	13	10

	Surface Roughness Ra** (µm)
H	--
V	11

	Relative Density (%)		Hardness (HV10)		Poisson's Ratio	
Thermal State	H	V	H	V	H	V
As-Built	99.9	99.9	362	--	--	--
SR1	99.9	99.9	--	--	--	--
SR2	99.9	99.9	--	--	--	--
SR3+HIP	99.9	99.9	--	--	--	--

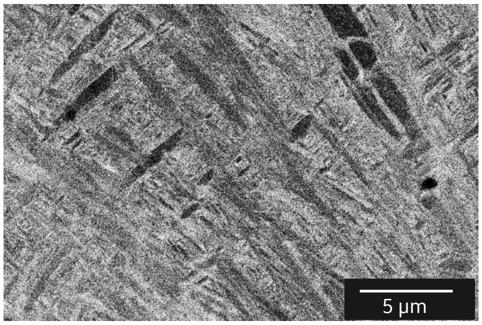
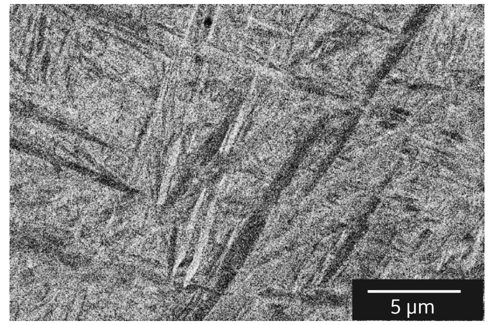
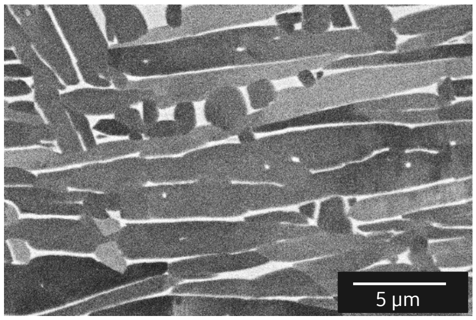
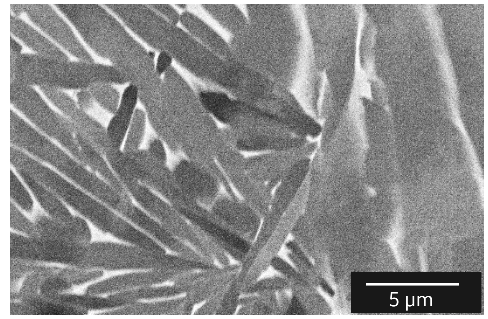
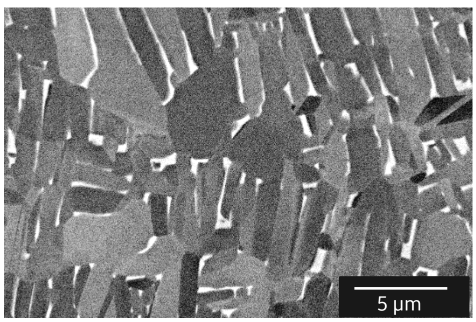
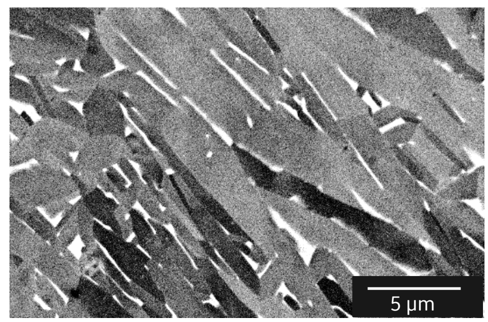
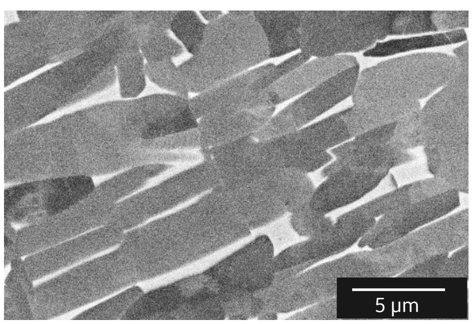
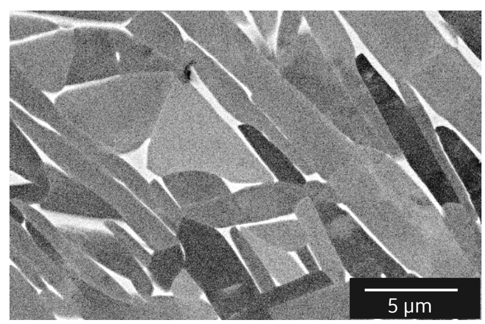
TENSILE DATA

Tensile testing done in accordance with ASTM E8 and ASTM E21

Test Temperature: RT	Modulus of Elasticity (GPa)		0.2% Yield Strength (MPa)		Ultimate Tensile Strength (MPa)		Elongation (%)		Reduction of Area (%)	
Thermal State	H	V	H	V	H	V	H	V	H	V
As-Built	112	111	1085	1040	1225	1185	5.7	7.9	--	--
SR1	115	112	925	865	1015	990	13.3	13.7	--	--
SR2	116	114	990	930	1050	1030	12.4	14.3	--	--
SR3+HIP	115	112	915	850	1010	990	13.8	15.4	--	--

H: HORIZONTAL (XY) orientation
V: VERTICAL (Z) orientation

* All of the figures contained herein are approximate only. The figures provided are dependent on a number of factors, including but not limited to, process and machine parameters, and the approval is brand specific and/or application specific. The information provided on this material data sheet is illustrative only and cannot be relied on as binding.
** Roughness measurements have been performed according to DIN EN ISO 4287 and DIN EN ISO 4288. In general analysis of the surface quality is strongly dependent on the methodology used and therefore deviations might be observed depending on methodology used. Vertical and horizontal sidewalls have been characterized using a tactile system, overhangs using an optical system.

	Horizontal	Vertical
As-Built		
SR1		
SR2		
HIP		

H: HORIZONTAL (XY) orientation
V: VERTICAL (Z) orientation

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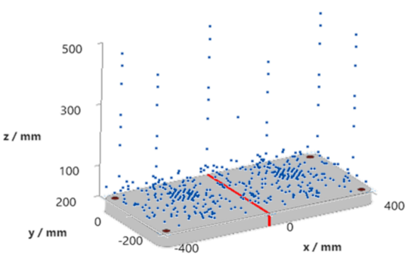
Within 3 platform stability builds porosity, roughness and tensile properties across different positions and orientations are evaluated. To illustrate the position dependency of the X Line 2000R, the samples were homogenously distributed across platform and height. Regarding surface quality all sides of the specimen, so all orientations with respect to gas flow and optical system, are included in the analysis. Data shown below are dependent on part & print layout as well as batch chemistry variations and thus might deviate from “typical values” given on previous pages.

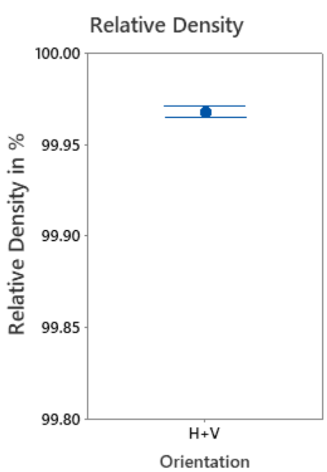
BUILD JOB DESIGN AND SUMMARIZED DATA (AS-BUILT)

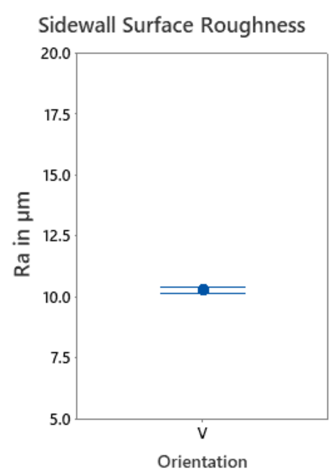


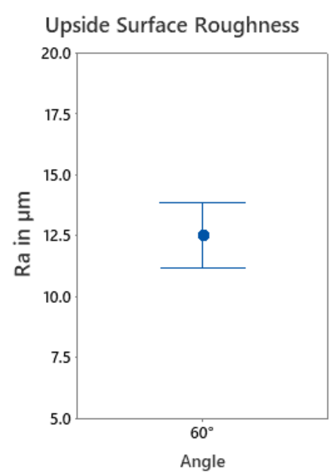
	Sample Size	Mean	St.Dev.
Rel. Density in %	236	99.97	0.02
Sidewall Roughness Ra in µm	552	10	2
Upside Roughness Ra in µm (60°)	16	13	3
Downside Roughness Ra in µm (60°)	16	12	3

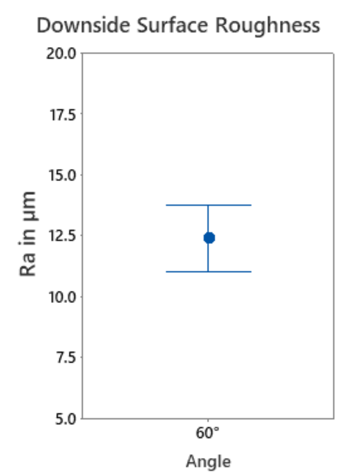
	Sample Size	Mean	St.Dev.
YM in GPa (H/V)	79/94	112/111	3/2
YS in MPa (H/V)	79/94	1087/1045	11/15
UTS in MPa (H/V)	79/94	1230/1188	10/14
Elongation in % (H/V)	79/94	5.7/8.0	0.9/2.0

RESULTS – RELATIVE DENSITY AND SURFACE QUALITY

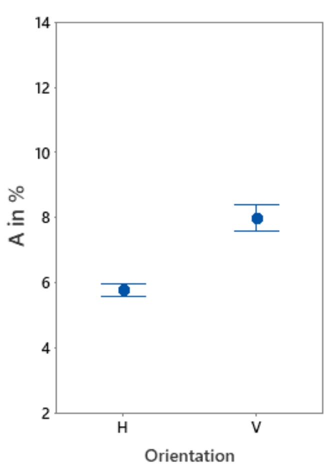


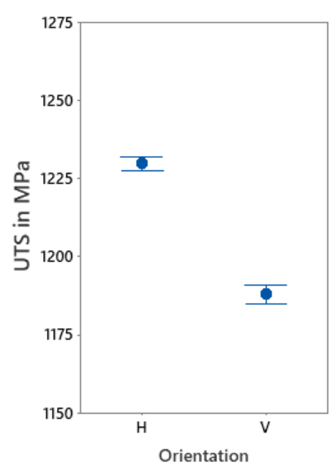


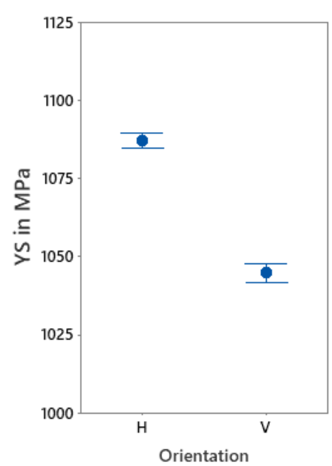


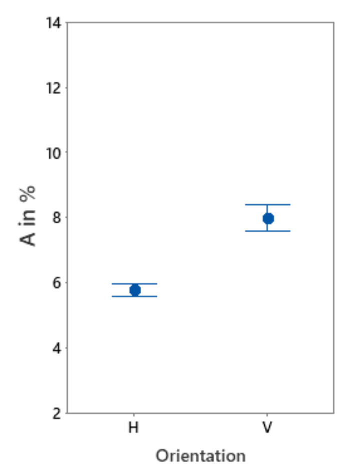


RESULTS - MECHANICAL PROPERTIES IN AS-BUILT CONDITION









Data points represent the mean value, intervals the 95% confidence level.

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