GE Additive

13 Al

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

M2 Series 5 Ti6Al4V Grade 23

Base Parameters for Concept Laser M2 Series 5

Data in this material datasheet represents material built with 30 µm and 60 µm layer thickness and in an Argon atmosphere on a Concept Laser M2 Series 5 single laser or dual laser machine, 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. Due to its proven biocompatibility and its long history in the medical industry it is an established material used for medical applications such as medical implants.

M2 Series 5 Ti6Al4V Grade 23

The Base and Productivity Parameters for the Concept Laser M2 Series 5 are developed leveraging the performance of the previous M2 generations of Ti6Al4V parameters.
The Base parameter is a 30 µm parameter that produces surface roughness less than 10 µm without bead blast or shot peening, while providing good productivity with dual lasers.
The Productivity parameter is a 60 µm parameter that provides nearly double the productivity, but with a higher surface roughness. By utilizing both parameters with Skin/Core functionality, the user can achieve a balance of productivity and surface finish.

M2 Series 5 Ti6Al4V Grade 23

With an appropriate approval* Ti6Al4V Grade 23 can be used for aerospace, orthopedic, and dental applications.

Data in this material datasheet represents material built with 30 µm and 60 µm layer thickness and in an Argon atmosphere on a Concept Laser M2 Series 5 single laser or dual laser machine, and requires build plate heating. Values listed are typical.

POWDER CHEMISTRY

Ti6Al4V Grade 23 powder chemical composition according to ASTM F136-02a (ELI Grade 23). For additional information on Ti6Al4V Grade 23 powder, visit AP&C.

MACHINE CONFIGURATION

- Concept Laser M2 Series 5 (Single Laser or Dual Laser)
- Argon gas

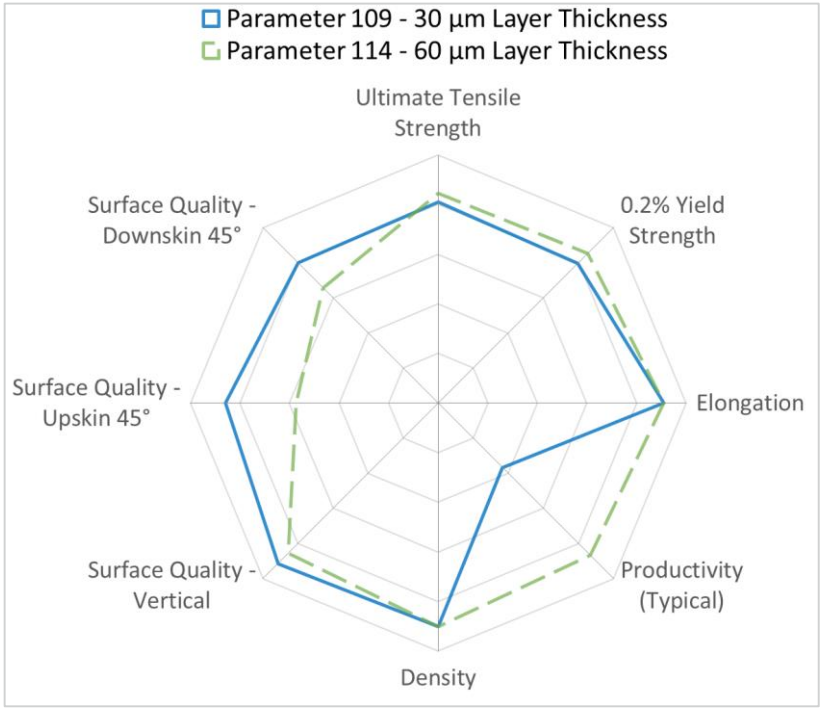
AVAILABLE PARAMETERS

- **Base Parameter 109** M2 Series 5 Titanium Ti6Al4V– 30 µm layer thickness
- **Productivity Parameter 114** M2 Series 5 Titanium Ti6Al4V– 60 µm layer thickness

THERMAL STATES

1. As-Built
2. Stress Relief SR1: 900°C, 1 hour
3. Stress Relief SR2: 840°C, 2 hours
4. Stress Relief SR3: 730°C, 2 hours

SPIDER PLOT (THERMAL STATE SR1)



Spider Plot is generated by normalizing typical material data (containing both horizontal and vertical data) against a range defined for each material family. For **Titanium Alloys,** the ranges are as follows: UTS: 0-1200 MPa, 0.2%YS: 0-1100 MPa, Elongation: 0-20%, Density: 99-100%, Productivity: 5-30 cm³/hr, Surface Quality (all): 50-4 µm

TYPICAL BUILD RATE

	(cm³/h)
Typical build rate[1] w/coating	11
Theoretical melting rate[2] bulk per Laser	13

[1]Measured by using standard Factory Acceptance Test layout
[2]Calculated (layer thickness x scan velocity x hatch distance)

PHYSICAL DATA AT ROOM TEMPERATURE

Surface Roughness – Overhang (µm)

	45°	60°	75°
Upskin	10	9	8
Downksin	12	9	8

Surface Roughness (µm)

H	6
V	8

Thermal State	Porosity (% Density) H	Porosity (% Density) V	Hardness (HV10) H	Hardness (HV10) V	Poisson's Ratio H	Poisson's Ratio V
As-Built	99.9	99.9	358	--	--	--
SR1	99.9	99.9	332	--	--	--

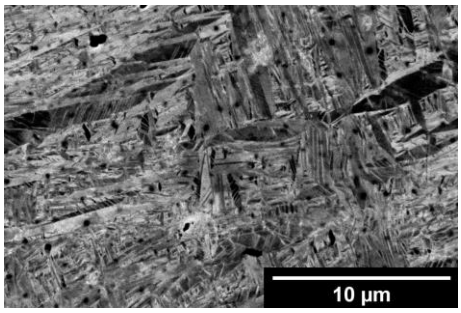
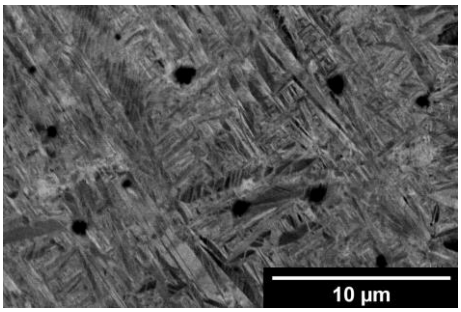
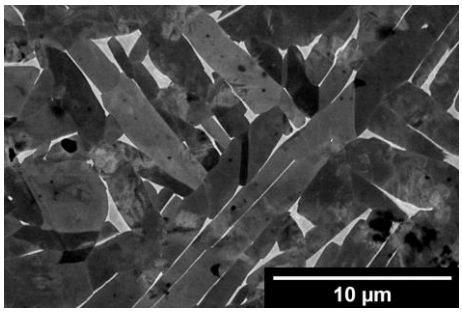
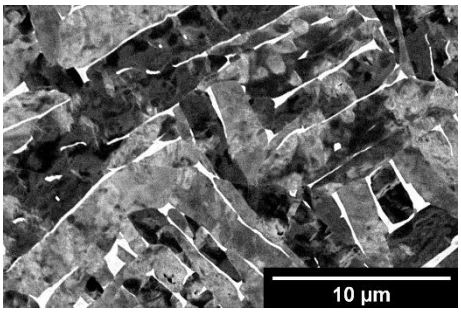
TENSILE DATA

Tensile testing done in accordance with ASTM E8 and ASTM E21

Temperature: RT

Thermal State	Modulus of Elasticity (GPa) H	Modulus of Elasticity (GPa) V	0.2% Yield Strength (MPa) H	0.2% Yield Strength (MPa) V	Ultimate Tensile Strength (MPa) H	Ultimate Tensile Strength (MPa) V	Elongation (%) H	Elongation (%) V	Reduction of Area (%) H	Reduction of Area (%) V
As-Built	113	107	1035	955	1185	1100	7.0	13.5	--	--
SR1	119	113	925	830	980	965	14.0	16.5	--	--

SEM IMAGES

	Horizontal	Vertical
As built		
SR1		

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.

TYPICAL BUILD RATE

Productivity Parameter 114

	(cm³/h)
Typical build rate[1] w/coating	26
Theoretical melting rate[2] bulk per Laser	40

[1]Measured by using standard Factory Acceptance Test layout
[2]Calculated (layer thickness x scan velocity x hatch distance)

PHYSICAL DATA AT ROOM TEMPERATURE

	Surface Roughness – Overhang (µm)		
	45°	60°	75°
Upskin	20	17	13
Downksin	17	13	9

	Surface Roughness (µm)
H	18
V	10

	Porosity (% Density)		Hardness (HV10)		Poisson's Ratio	
Thermal State	H	V	H	V	H	V
As-Built	99.9	99.9	357	--	--	--
SR1	--	--	342	--	--	--

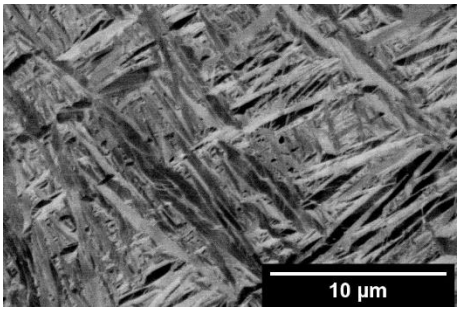
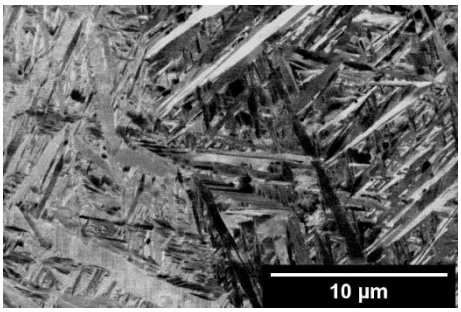
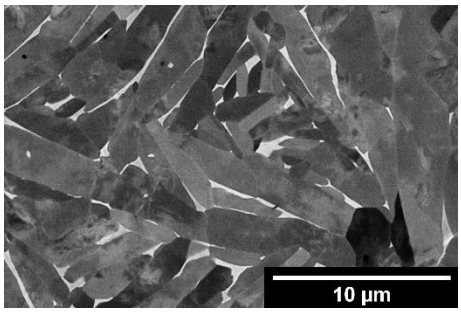
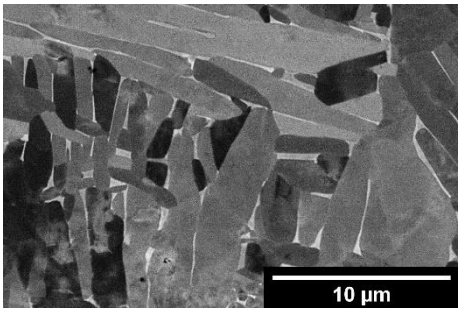
TENSILE DATA

Tensile testing done in accordance with ASTM E8 and ASTM E21

Temperature: RT

	Modulus of Elasticity (GPa)		0.2% Yield Strength (MPa)		Ultimate Tensile Stregth (MPa)		Elongation (%)		Reduction of Area (%)	
Thermal State	H	V	H	V	H	V	H	V	H	V
As-Built	113	112	1115	1125	1255	1275	7.0	8.0	--	--
SR1	121	118	940	940	1015	1015	16.0	14.5	--	--
SR2	118	119	995	995	1050	1050	13.5	14.5	--	--
SR3	119	120	1080	1075	1135	1130	12.0	11.5	--	--

SEM IMAGES

	Horizontal	Vertical
As built		
SR1		

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

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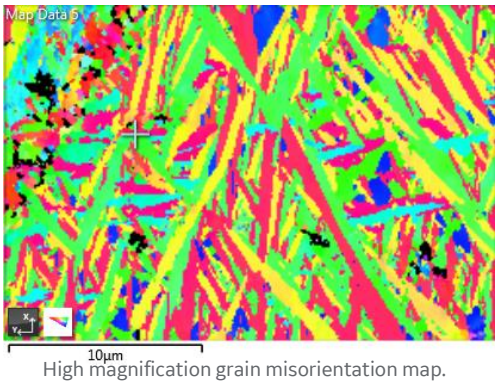
EBSD investigations for Ti64 (exemplary for Parameter 114 - 60µm layer thickness)

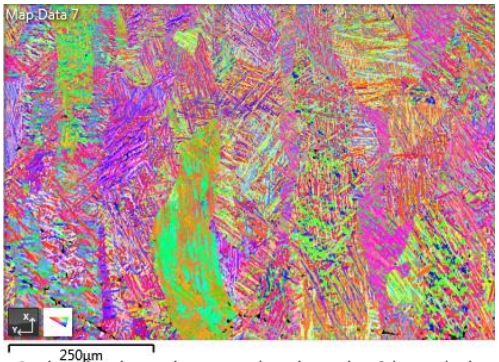
As built condition, vertical direction

5000x



High magnification grain misorientation map.

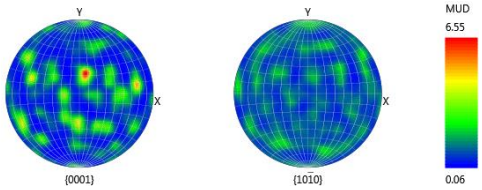
150x



Grain misorientation map showing prior β boundaries as well as a preferential {0001} texture.

150x – PF

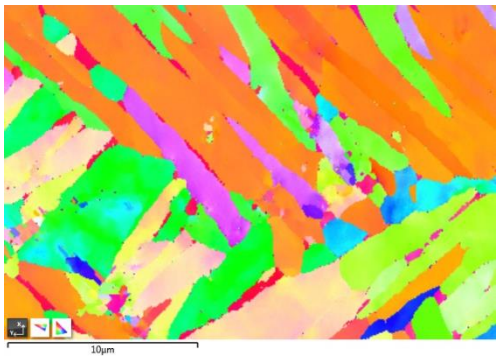
α-phase



Pole figure verifying presence of {0001} texture. This is also reflected in the directional tensile properties.

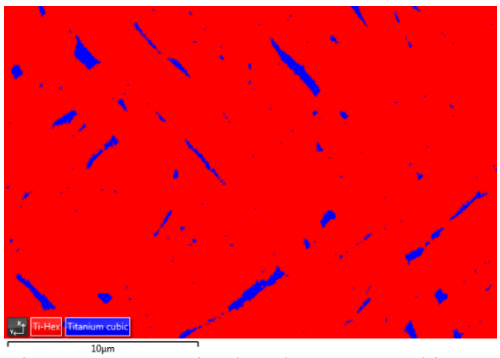
SR1 condition, vertical direction

5000x



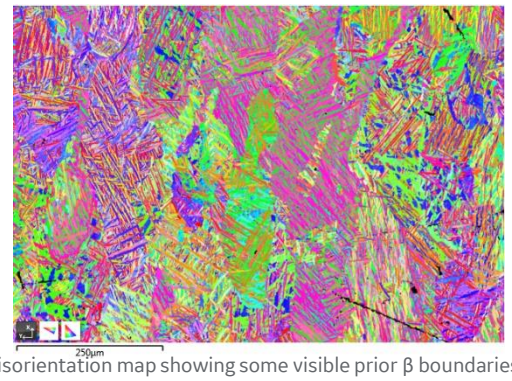
High magnification grain misorientation map.

5000x



α-β-phase content map showing microstructure with a small amount of beta phase, typical after heat treating Ti64.

150x

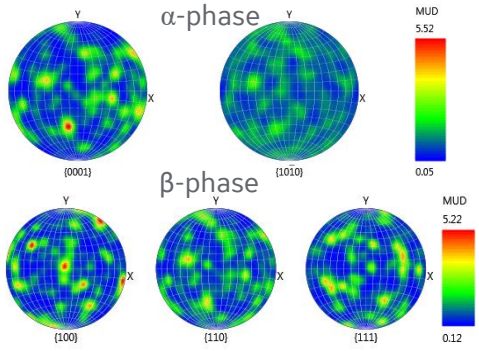


Grain misorientation map showing some visible prior β boundaries, as well as a reduction in preferential orientation compared to the as-built condition.

150x – PF

α-phase

β-phase



Pole figure verifying presence of {0001} texture in the α phase, as well as some texture in the remaining β-phase.

GE Additive

13 Al

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

M2 Series 5 Ti6Al4V Mesh+ Parameters

Premium+ Parameters for Concept Laser M2 Series 5

Data in this material datasheet represents material built with 30 µm and 60 µm layer thickness and in an Argon atmosphere on a Concept Laser M2 Series 5 single laser or dual laser machine, and requires build plate heating. Values listed are typical.

Titanium Ti6Al4V

Titanium shows a high corrosion resistance and proven biocompatibility and has been employed successfully in human implant applications in contact with soft tissue and bone for decades.
Porous (trabecular) structures are very common for AM manufactured medical implants. The open titanium architecture results in open structures that lead to enhanced osseointegration and allows adjusting the final device characteristics (density, stiffness), it also requires well balanced parameter set to optimize the build process fulfilling the productivity and quality requirements .

M2 Series 5 Ti6Al4V Mesh+ Parameters

The Mesh+ parameter enables the user to design porosity and pore size, as well as interconnectivity of trabecular structures to allow for enhanced initial fixation and bone ingrowth. The parameter further provides the user with an exceptional balance of high grade of detail and high productivity.
The Mesh+ parameters can be used in conjunction with the Concept Laser M2 Series 5 Ti6Al4V Base and Productivity parameters to create parts with both solid and mesh volumes to create hybrid components.

M2 Series 5 Ti6Al4V Grade 23 Mesh+

With an appropriate approval* Ti6Al4V Grade 23 can be used for medical applications.

Data in this material datasheet represents material built with 30 µm and 60 µm layer thickness and in an Argon atmosphere on a Concept Laser M2 Series 5 single laser or dual laser machine, and requires build plate heating. Values listed are typical.

POWDER CHEMISTRY

Ti6Al4V Grade 23 powder chemical composition according to ASTM F136-02a (ELI Grade 23). For additional information on Ti6Al4V Grade 23 powder, visit AP&C.

MACHINE CONFIGURATION

- Concept Laser M2 Series 5 (Single Laser or Dual Laser)
- Argon gas

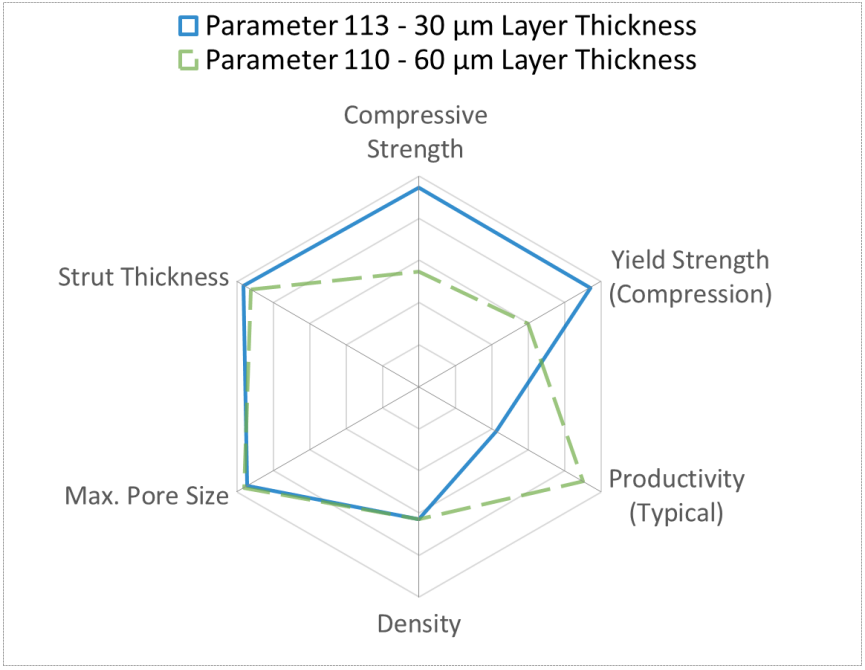
AVAILABLE PARAMETERS

- **Mesh+ Parameter 113**– 30 µm layer thickness
- **Mesh+ Parameter 110** – 60 µm layer thickness

THERMAL STATES

1. As-Built
2. Stress Relief SR1
   900°C, 1 hour
3. Hot Isostatic Press HIP
   900°C, 2 hrs, 100 MPa

SPIDER PLOT (THERMAL STATE SR1)



Spider Plot is generated by normalizing typical material data against a range defined for each material family. For **Titanium Alloys (mesh parameter),** the ranges are as follows: UTS 0-110 MPa, 0.2%YS: 0-85 MPa, Density: 0-100%, Productivity: 5-40 cm³/hr, Max. Pore Size: 0-510 µm, Strut Thickness: 0-260 µm

TYPICAL BUILD RATE

	(cm³/h)
Theoretical melting rate[2] bulk per Laser	17

[2]Calculated (layer thickness x scan velocity x hatch distance)

COMPRESSION STRENGTH OF MESH STRUCTURE[3]

Compression testing done in accordance with ISO 13314

	Modulus of Elasticity (Compression) (GPa)	Yield Strength (Compression) (MPa)	Compressive Strength (MPa)
As built	2.2	80	104
SR	2.5	81	104
HIP	2.3	76	100

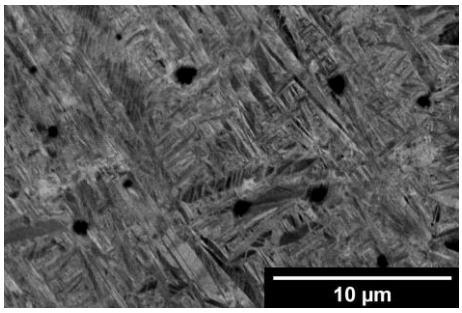
MESH DIMENSIONS**

	Mesh porosity (%)	Strut thickness (µm)	Max. pore size (µm)
As built	63	250	480

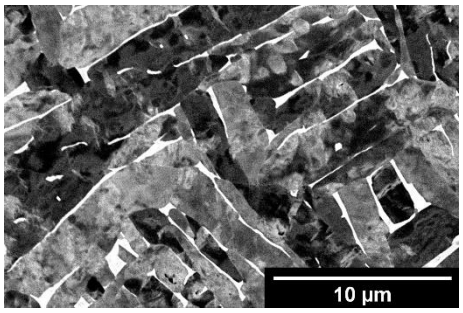
SEM & CAD IMAGES

Vertical (bulk)

As built

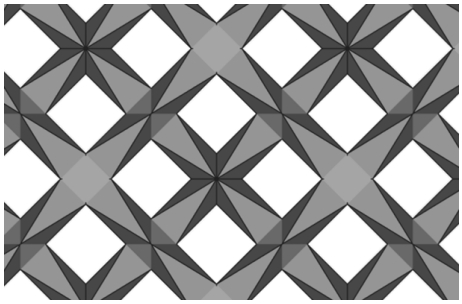


SR1



Mesh Structure

CAD Model[3]



SEM image

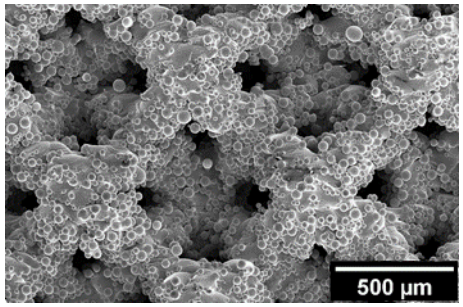


Image shows the as-built condition (no cleaning)

V: VERTICAL (Z) orientation

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[3] Data demonstrating results of special mesh design. Different designs could lead to changes in properties.

TYPICAL BUILD RATE

	(cm³/h)
Theoretical melting rate[2] bulk per Laser	36

[2]Calculated (layer thickness x scan velocity x hatch distance)

COMPRESSION STRENGTH OF MESH STRUCTURE[3]

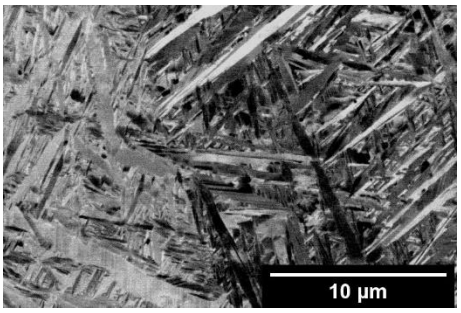
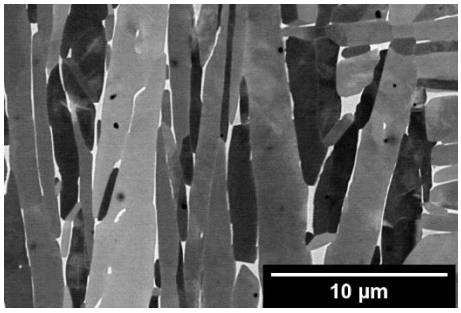
Compression testing done in accordance with ISO 13314

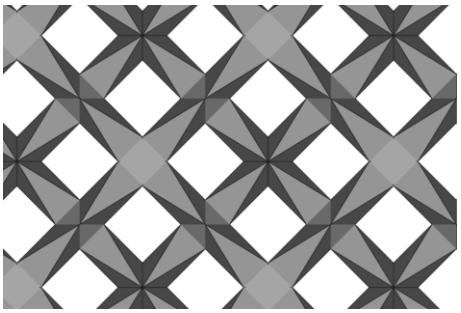
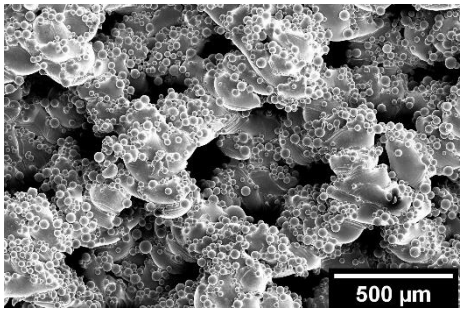
	Modulus of Elasticity (Compression) (GPa)	Yield Strength (Compression) (MPa)	Compressive Strength (MPa)
As built	1.2	51	60
SR	1.3	50	60
HIP	1.3	47	64

MESH DIMENSIONS**

	Mesh porosity (%)	Strut thickness (µm)	Max. pore size (µm)
As built	64	240	490

SEM & CAD IMAGES

	As built	SR1
Vertical (bulk)		

	CAD Model[3]	SEM image
Mesh Structure		 Image shows the as-built condition without cleaning

V: VERTICAL (Z) orientation

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[3] Data demonstrating results of special mesh design. Different designs could lead to changes in properties.