13 Al

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

# M2 Series 5 Steel 316L

## Parameters for GE Additive's Concept Laser M2 Series 5

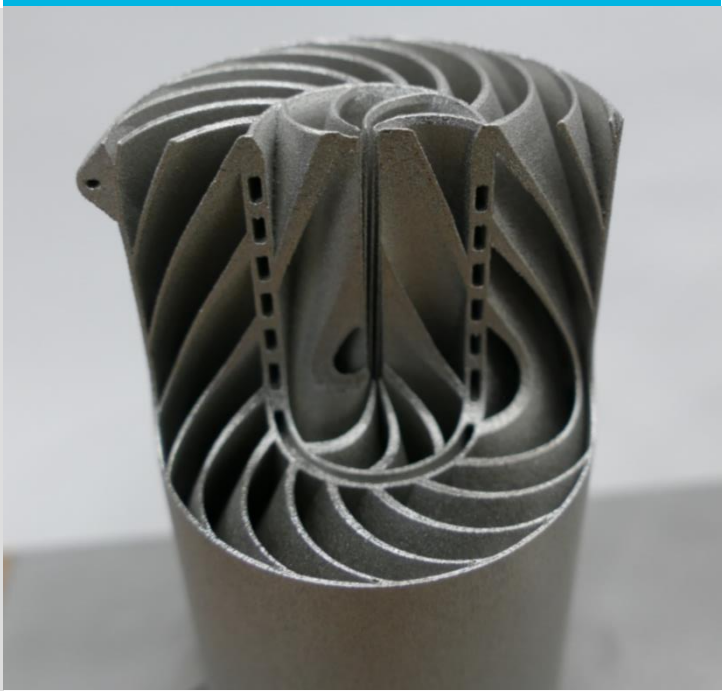
Data in this material datasheet represent material built with 25 and 50 µm layer thicknesses and in a nitrogen atmosphere on a Concept Laser M2 Series 5 single-laser or dual-laser machine. Values listed are typical.


### 316L Stainless Steel

316L is a chromium-nickel-molybdenum austenitic stainless steel having a higher corrosion resistance compared to the most common stainless steel 304 without any significant disadvantages in costs. By the addition of molybdenum this steel is particularly suitable for components within harsh chemical environments containing chlorides and other halides. Typical applications can be found across a wide range of industries like plant engineering, oil & gas industry, automotive, medical technology, and jewelry and components for molds. 316L is easily weldable and offers excellent ductility and high creep strength at elevated temperatures.

### M2 Series 5 Steel 316L

The 316L parameters for the Concept Laser M2 Series 5 are developed leveraging the performance of the previous M2. The base parameter deliver good surface quality while maintaining a very good density, mechanical strength and productivity. For highest all-around surface quality, particularly within overhang downskin and upskin regions, the surface parameter has been developed.
All parameters succeed the minimum tensile properties specified in ASTM F3184 for additive manufactured parts in the stress relieved state.



# M2 Series 5 Steel 316L

With corresponding approval* Steel 316L can be used for manufacturing components for acid- and corrosion-resistant applications in the following fields: plant engineering, automotive, medical technology, and jewelry and components for molds.

Data in this material datasheet represent material built with 25 and 50 µm layer thicknesses in a nitrogen atmosphere on a Concept Laser M2 Series 5 single-laser or dual-laser machine. Values listed are typical.

## POWDER CHEMISTRY

316L powder chemical composition according to ASTM F3184 - UNS S31603 / ASTM A276.

## MACHINE CONFIGURATION

- Concept Laser M2 Series 5 (single-laser or dual-laser)
- Nitrogen gas
- Rubber/Steel recoater blade

## AVAILABLE PARAMETERS

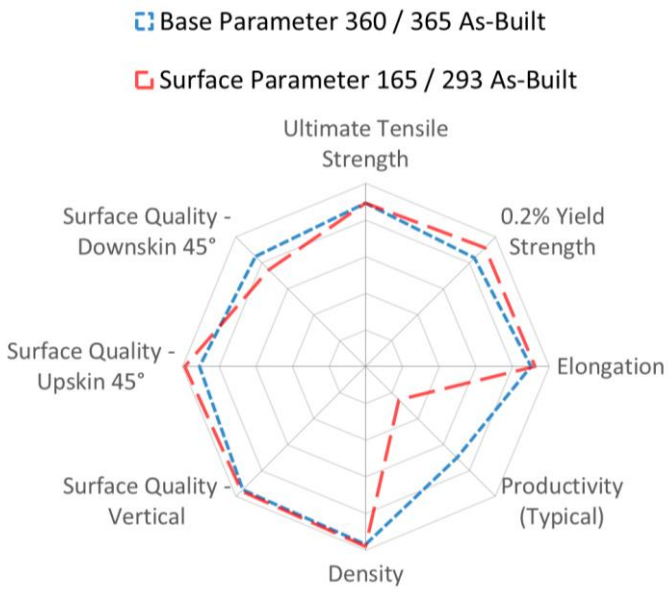
- **Base Parameter 360**** 50 µm layer thickness, steel recoater
- **Base Parameter 365**** 50 µm layer thickness, rubber recoater
- **Surface Parameter 165 / 293**** 25 µm layer thickness, rubber recoater

**productivity optimized version (productivity bundle required)

## THERMAL STATES

1. As-Built
2. Stress Relief according to AMS2759/11A (SR1)
   SR1: 1h at 899°C, with air cooling
3. Solution Anneal according to AMS2659/4D (SOLN1)
   SOLN1: 1h at 1066°C, with air cooling
4. Solution Anneal (SOLN2)
   SOLN2: 4h at 1100°C, with water quench

## PARAMETER 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 **Stainless Steels**, the ranges are as follows: UTS: 0-750 MPa, 0.2%YS: 0-650 MPa, Elongation: 0-70 %, Density: 99-100 %, Productivity: 5-30 $cm^3/h$, Surface Quality (all): 5-50 µm

## TYPICAL BUILD RATE

**Base Parameter**

| | (cm³/h) |
|---|---|
| Typical build rate[1] w/coating | 21.1 |
| Theoretical melting rate[2] bulk per Laser | 17.8 |

[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 | 10 | 7 | 6 |
| Downskin | 12 | 10 | 7 |

| | Surface Roughness Ra** (µm) |
|---|---|
| H | 9 |
| V | 8 |

| | Relative Density (%) | | Hardness (HV10) | | Poisson's Ratio | |
|---|---|---|---|---|---|---|
| **Thermal State** | H | V | H | V | H | V |
| As-Built | 99.9 | 99.9 | 213 | -- | -- | -- |
| SR1 | -- | -- | 187 | -- | -- | -- |
| SOLN1 | -- | -- | 180 | -- | -- | -- |
| SOLN2 | -- | -- | 144 | -- | -- | -- |

## TENSILE DATA

Tensile testing done in accordance with ASTM E8 and ASTM E21

**Test Temperature: RT**

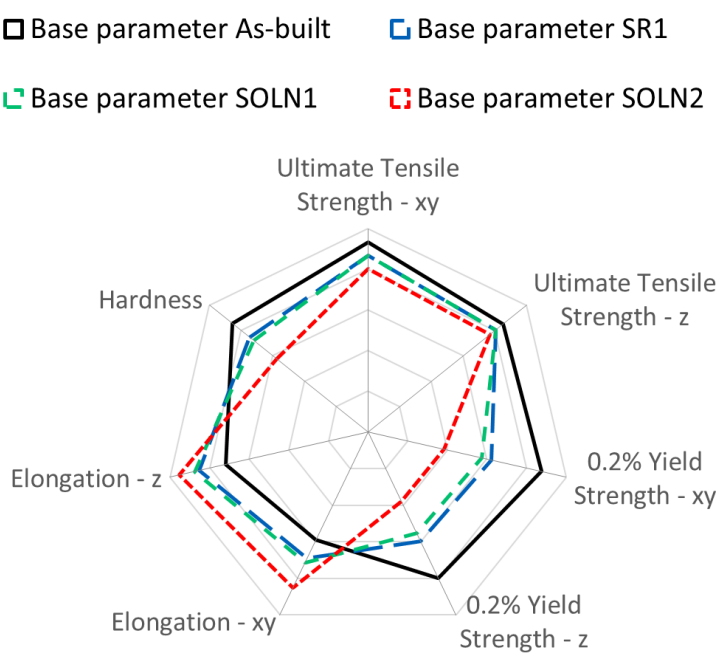
| | Modulus of Elasticity (GPa) | | 0.2% Yield Strength (MPa) | | Ultimate Tensile Strength (MPa) | | Elongation (%) | | Reduction of Area (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Thermal State** | H | V | H | V | H | V | H | V | H | V |
| As-Built | 188 | 161 | 565 | 520 | 695 | 635 | 41.0 | 50.0 | 68.5 | 72.5 |
| SR1 | 197 | 197 | 405 | 385 | 650 | 600 | 48.0 | 59.5 | 67.0 | 71.5 |
| SOLN1 | 200 | 198 | 370 | 360 | 650 | 600 | 49.5 | 61.0 | 64.5 | 71.5 |
| SOLN2 | 190 | 182 | 250 | 245 | 600 | 575 | 59.5 | 66.5 | 63.5 | 68.5 |

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 deviations might be caused by different measurement set up. Vertical and horizontal sidewalls have been characterized using a tactile system, overhangs using an optical system.

## THERMAL STATE COMPARISON

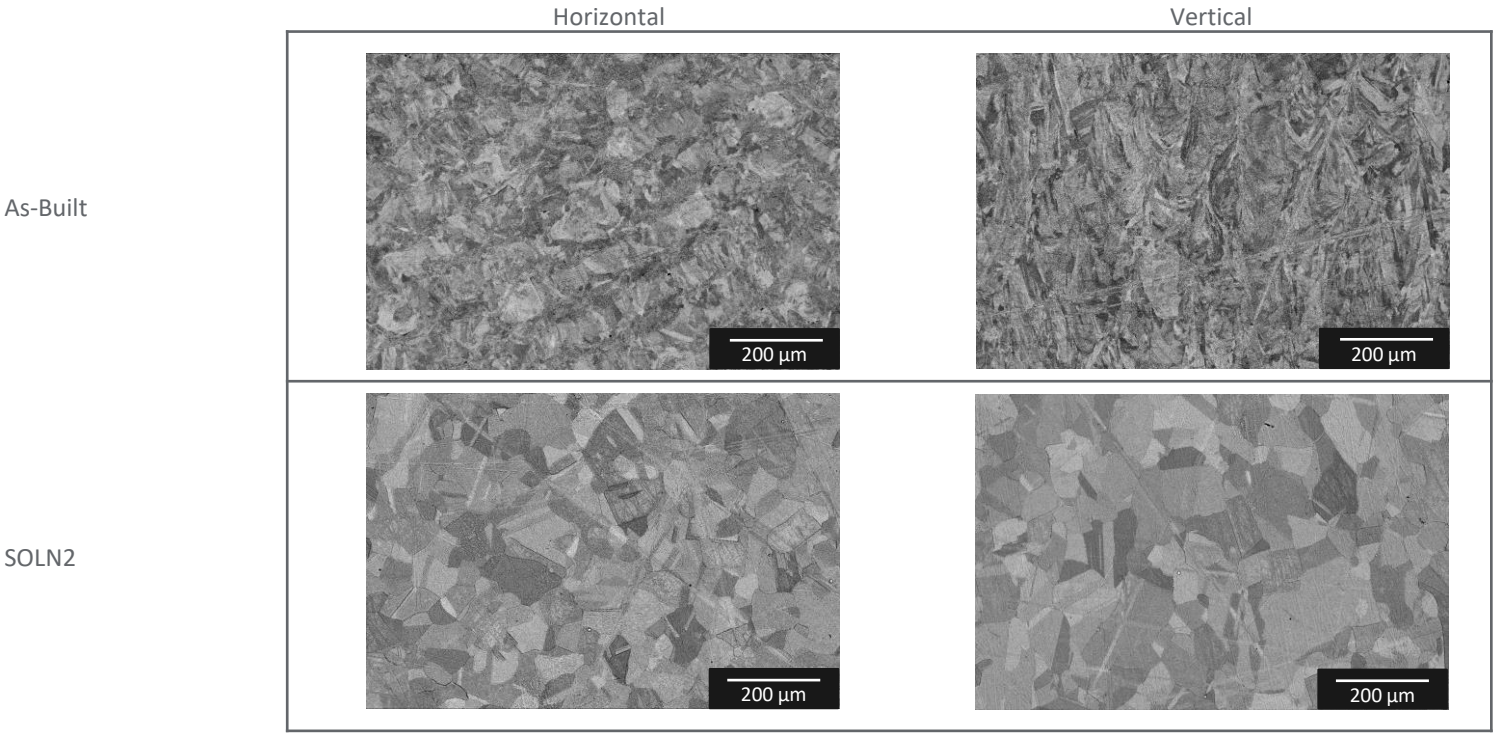
Base Parameter




Spider Plot is generated by normalizing typical material data (containing both horizontal and vertical data) against a range defined for each material family. For **Stainless Steels**, the ranges are as follows: UTS: 0-750 MPa, 0.2%YS: 0-650 MPa, Elongation: 0-70 %, Hardness: 0-250 HV10

## SEM IMAGES (low magnification)

Base Parameter




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

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## PLATFORM STABILITY

**Base Parameter**

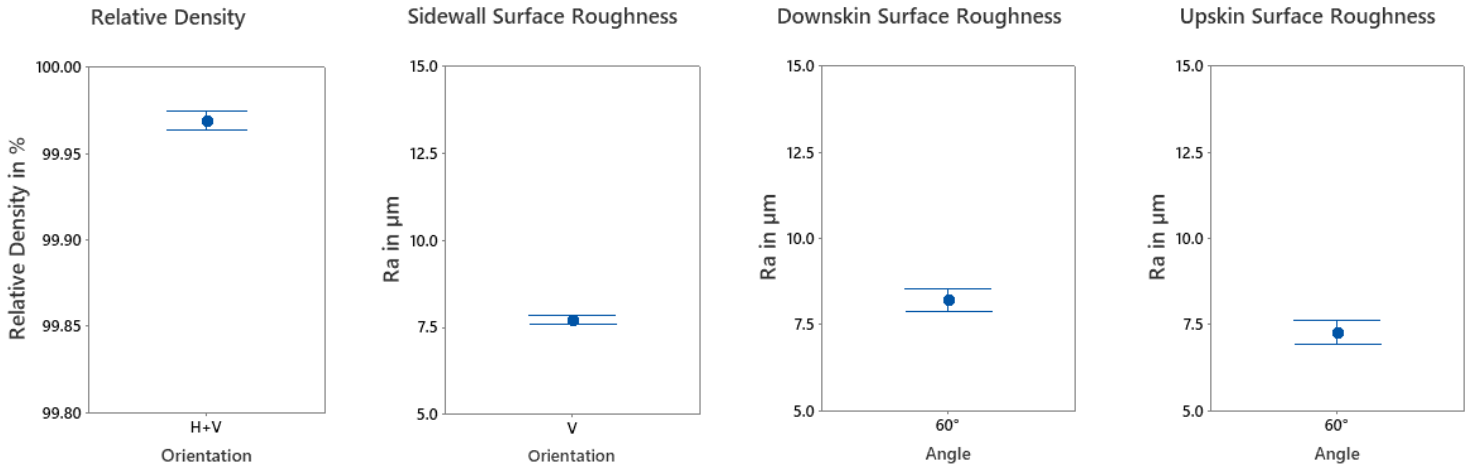
The platform stability build evaluates porosity, roughness and tensile properties across different positions and orientations. To illustrate the position dependency of the M2 Series 5, the samples were homogenously distributed across the platform on 16 different positions. Regarding surface quality all sides of the specimen, so all orientations with respect to gas flow and optical system, are included in the analysis. Data shown below is dependent on part & print layout as well as batch chemistry and thus might deviate from “typical values” given on previous pages.

## BUILD JOB DESIGN AND SUMMARIZED DATA (AS-BUILT)

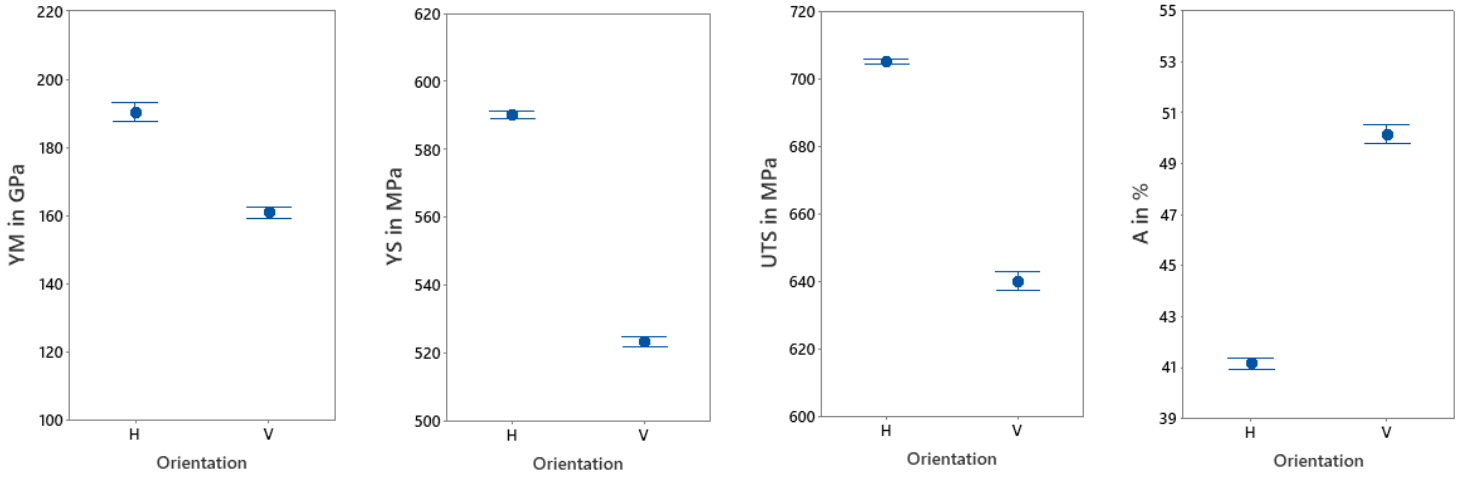
| | Sample Size | Mean | St.Dev. |
|---|---|---|---|
| Rel. Density in % | 32 | 99.97 | 0.02 |
| Sidewall Roughness Ra in µm | 64 | 8 | 1 |
| Upskin Roughness Ra in µm (60°) | 64 | 8 | 1 |
| Downskin Roughness Ra in µm (60°) | 64 | 8 | 1 |

| | Sample Size | Mean | St.Dev. |
|---|---|---|---|
| YM in GPa (H/V) | 16/16 | 190/161 | 6/4 |
| YS in MPa (H/V) | 16/16 | 590/523 | 3/3 |
| UTS in MPa (H/V) | 16/16 | 705/640 | 2/6 |
| Elongation in % (H/V) | 16/16 | 41.1/50.1 | 0.5/0.7 |

## RESULTS – RELATIVE DENSITY AND SURFACE QUALITY




## RESULTS - MECHANICAL PROPERTIES IN AS-BUILT CONDITION




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

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

## TYPICAL BUILD RATE

## Surface Parameter

| | Standard (cm³/h) | Productivity optimized (cm³/h) |
|---|---|---|
| Typical build rate[1] w/coating | 7.7 | 9.3 |
| Theoretical melting rate[2] bulk per Laser | 7.2 | 7.2 |

[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 | 6 | 5 | 5 |
| Downskin | 17 | 7 | 6 |

| | Surface Roughness Ra** (µm) |
|---|---|
| H | 9 |
| V | 7 |

| | Relative Density (%) | | Hardness (HV10) | | Poisson's Ratio | |
|---|---|---|---|---|---|---|
| **Thermal State** | H | V | H | V | H | V |
| As-Built | 99.9 | 99.9 | 220 | -- | -- | -- |
| SR1 | -- | -- | 220 | -- | -- | -- |

## 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 | 208 | 172 | 645 | 550 | 740 | 600 | 34.5 | 65.0 | -- | -- |
| SR1 | 205 | 189 | 610 | 520 | 765 | 600 | 31.5 | 52.1 | -- | -- |

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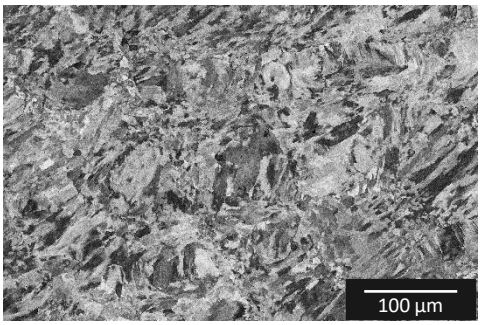
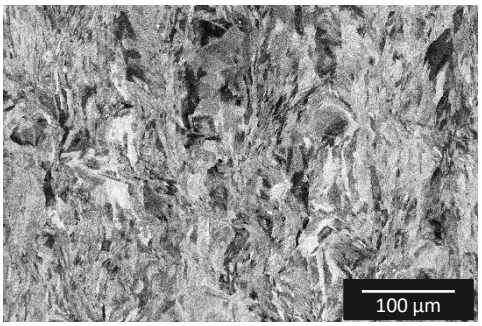
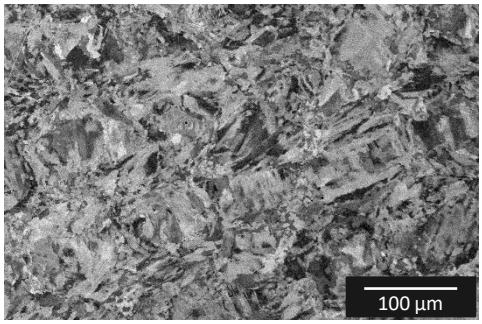
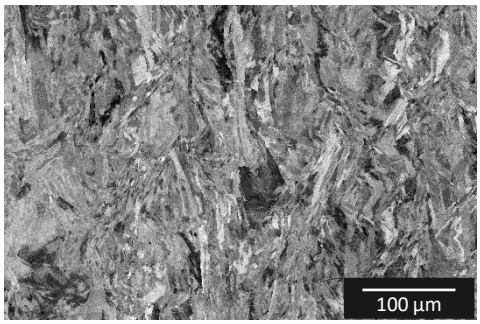
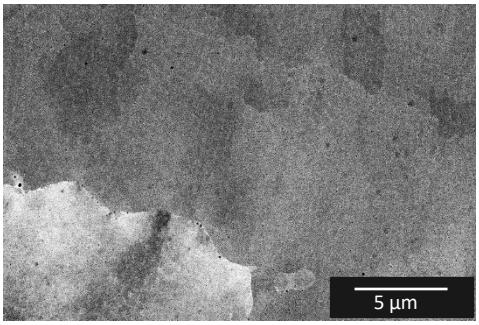
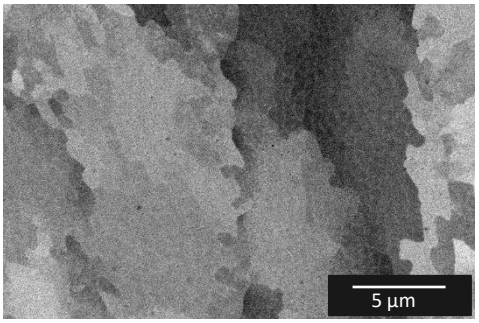
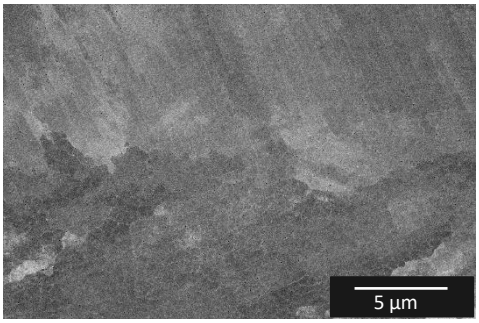
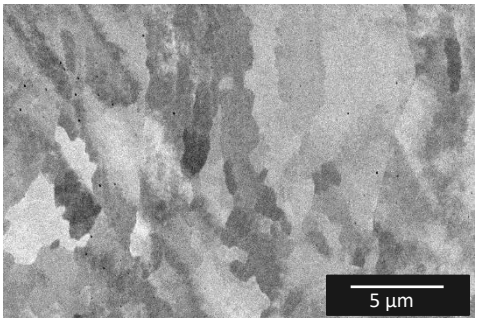
** Roughness measurements have been performed according to DIN EN ISO 4287 and DIN EN ISO 4288. In general analysis of the surface quality is strongly dependent on the methodology used and deviations might be caused by different measurement set up. Vertical and horizontal sidewalls have been characterized using a tactile system, overhangs using an optical system.

## SEM IMAGES (low magnification)



| | Horizontal | Vertical |
|---|---|---|
| As-Built |   |   |
| SR1 |   |   |

## SEM IMAGES (high magnification)

| | Horizontal | Vertical |
|---|---|---|
| As-Built |   |   |
| SR1 |   |   |

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