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Development of new stainless steel via Laser powder bed fusion process

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Outline

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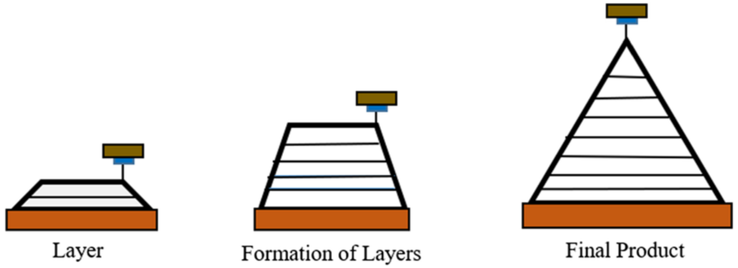
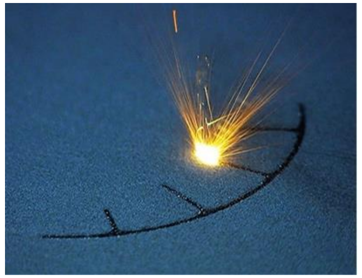
Introduction

Layer by Layer production of components by **CAD file**



Metal AM **Processes** (Powder Based)

- PBF
  - ✓ L-PBF
  - ✓ EB-PBF
- DED



Additive Manufacturing

Limitations

- Poor **surface quality**
- Low **build up** rate
- Limited available **materials**

How to **overcome** these **challenges**?

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Introduction

Challenges and solutions

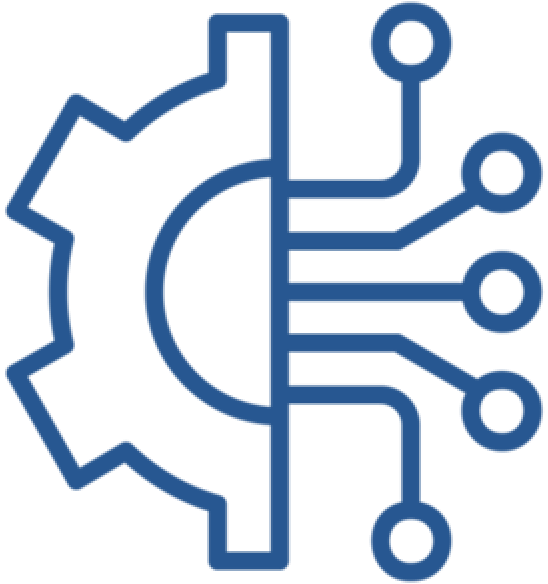
Material development

Process Parameter Optimization

SOLUTIONS

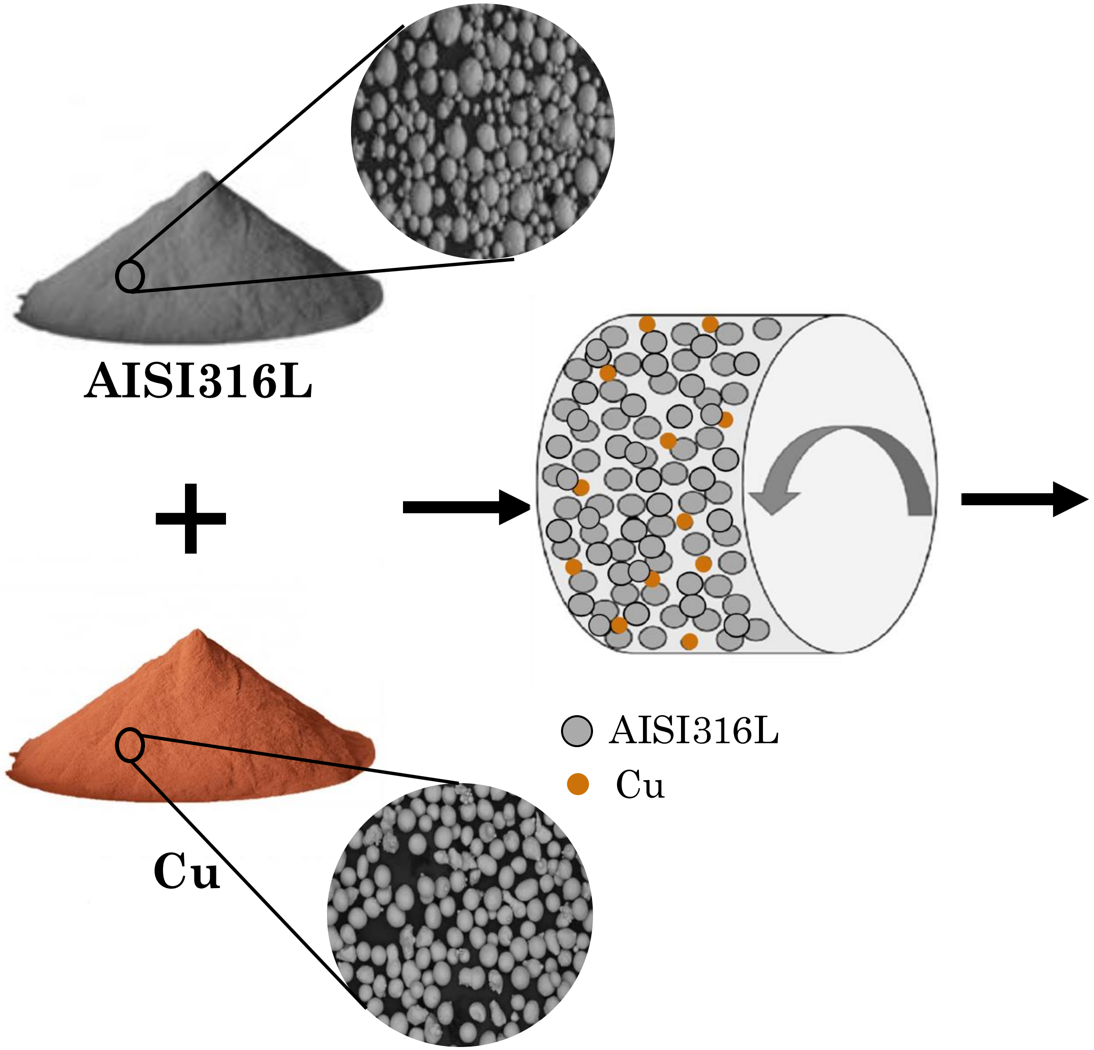
Machine Learning

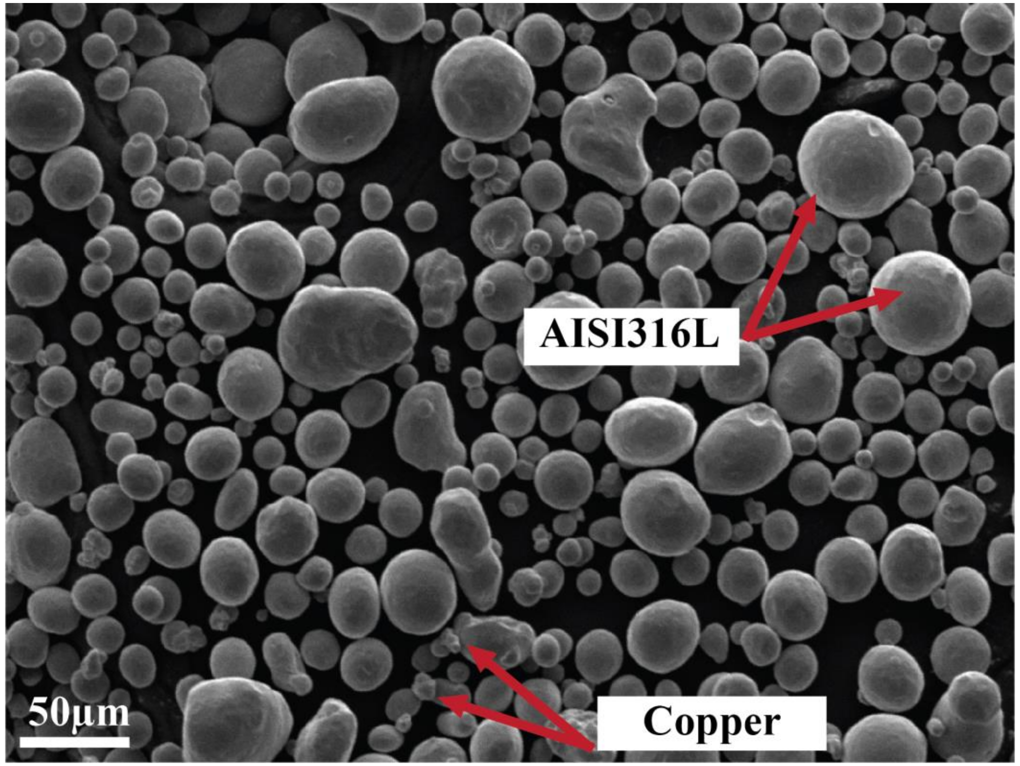
- Process parameter optimization
- In-situ monitoring
- Post process characterization



Materials and Methods

Powder Preparation: Jar milling (97.5%AISI316L+2.5%Cu)

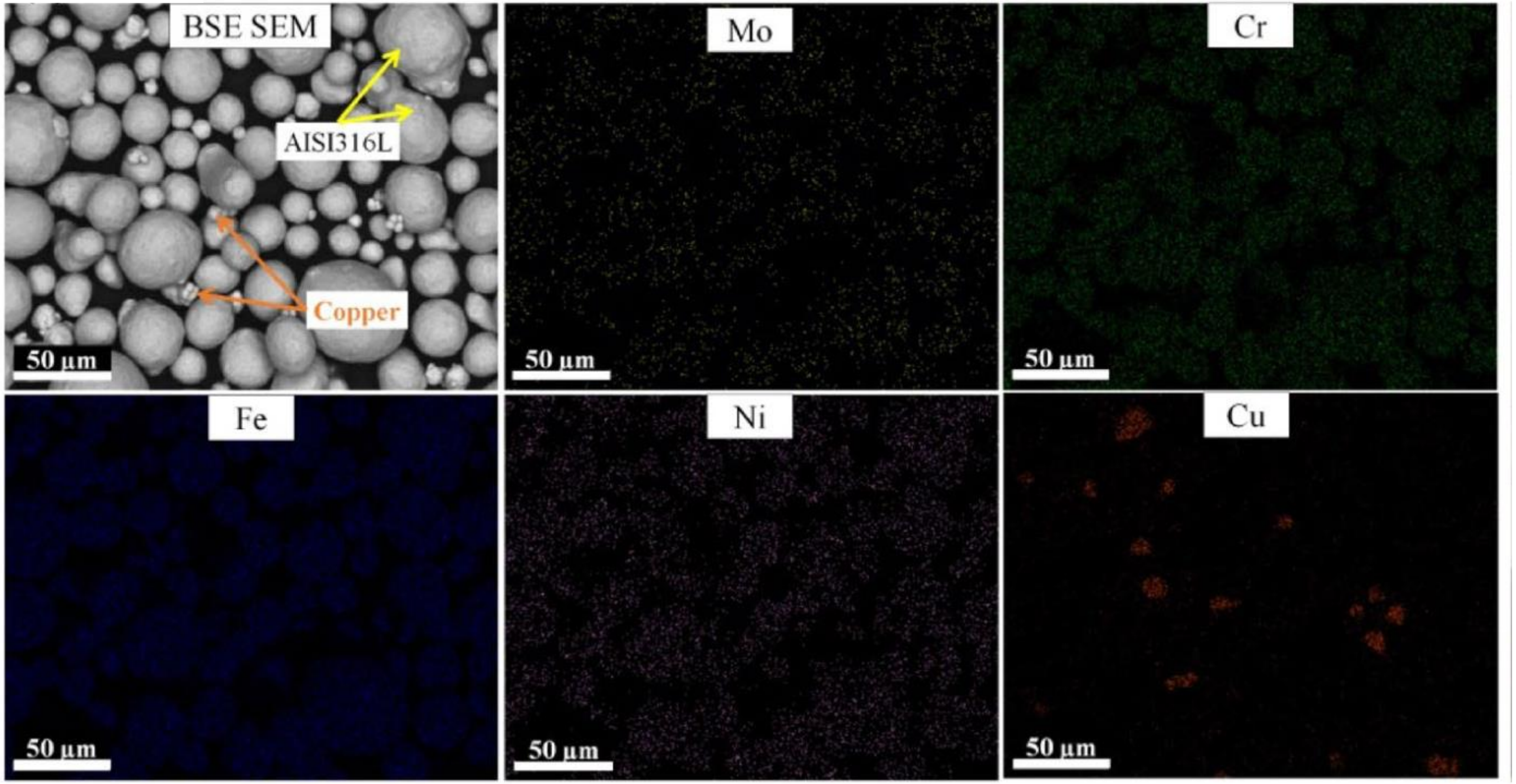




Mostly round particles, some hollow, with satellite particles

Materials and Methods

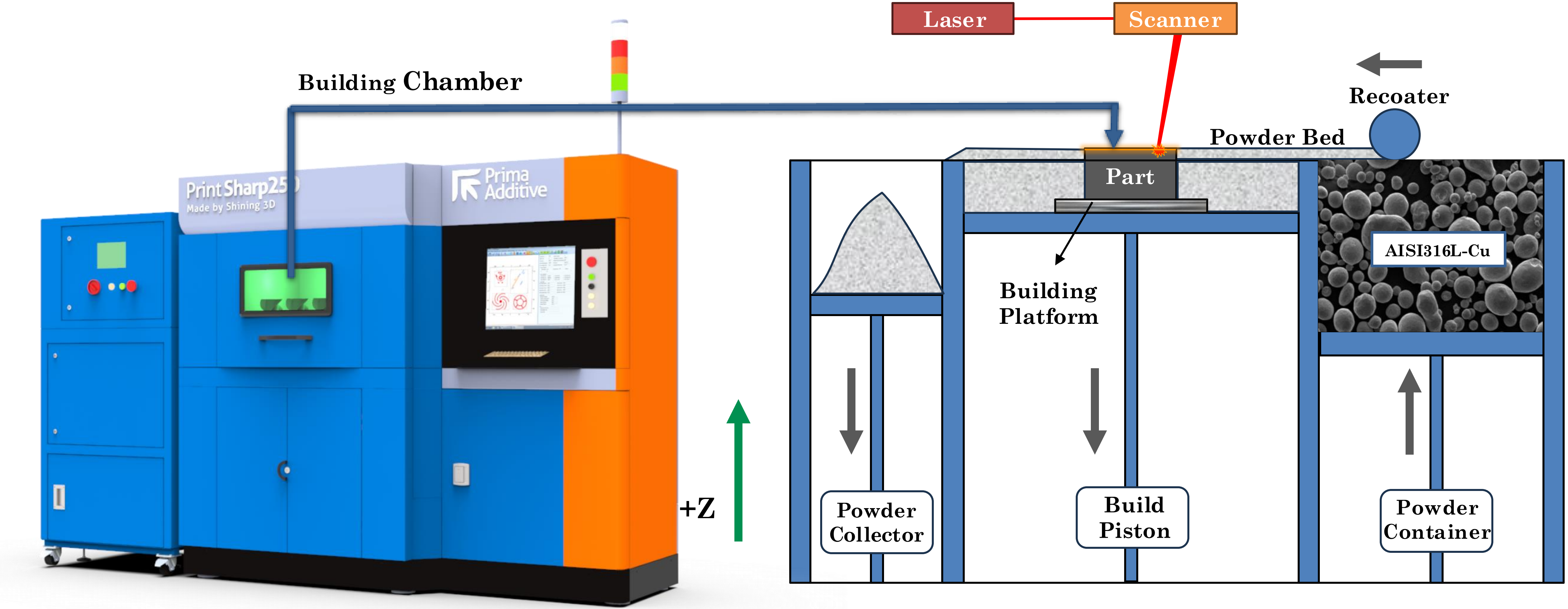
This BSE SEM image of the mixed powder is complemented by EDS elemental maps, showing the distribution of chemical elements within the material.



Materials and Methods

Laser Powder Bed fusion

Mechanism explanation: A laser beam is used to **selectively melt** fine metal **powder** and build up fully-dense parts **layer-by-layer**

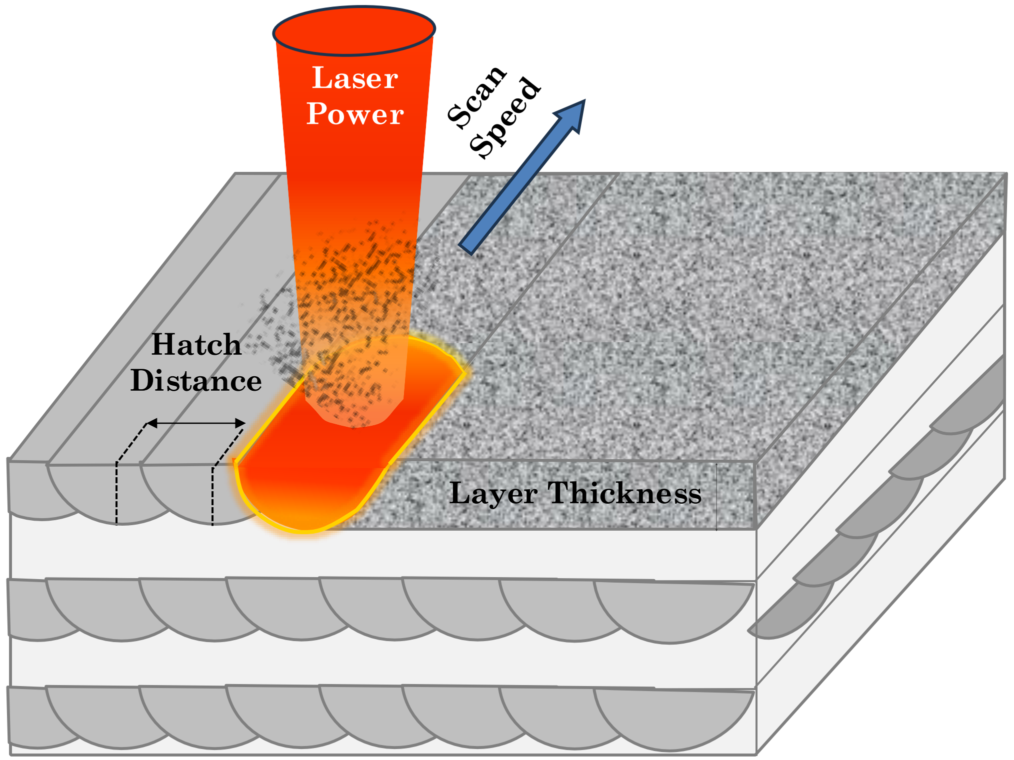


Materials and Methods

Design Of Experiments

64 different process parameters

- Power
  100, 190, 200, 270, 340 W
- Scan Speed
  400, 600, 800, 1000 mm/s
- Hatch Distance
  0.1, 0.11, 0.12, 0.13, 0.2 mm
- Layer Thickness
  0.03 mm



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Materials and methods

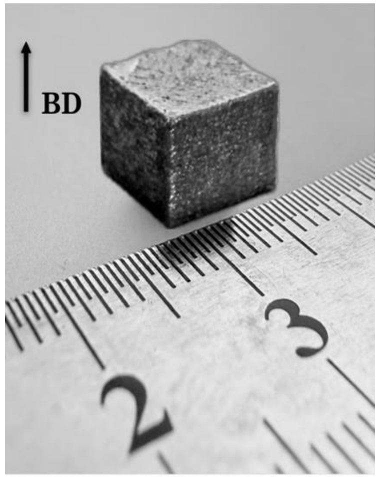
Design Of Experiments: 64 Cubic Specimens

Powder Feedstock: AISI316L-2.5%Cu

Metal AM Technology: L-PBF

Analyzed conditions: As-Built

Characterizations: Powder characteristics,Density,X-ray Computed Tomography,Image analysis, Microstructure analysis, Mechanical properties



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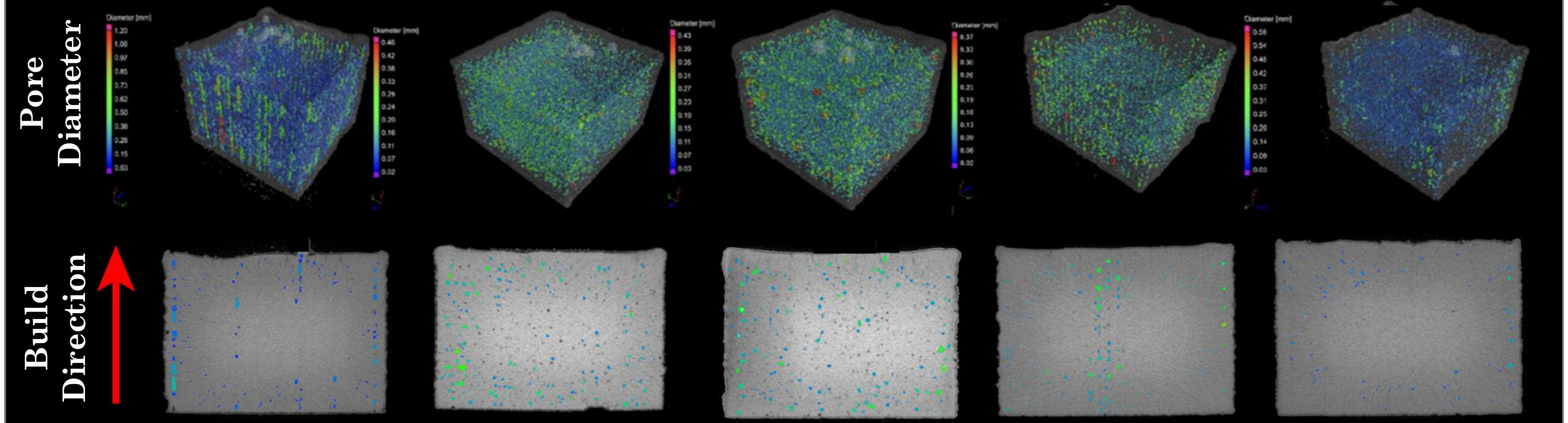
Result and Discussion

	P = 340 W V = 1000 mm/s H = 100 mm	P = 190 W V = 600 mm/s H = 110 mm	P = 200 W V = 400 mm/s H = 110 mm	P = 100 W V = 600 mm/s H = 120 mm	P = 190 W V = 1000 mm/s H = 130 mm



XCT Method	97.48%	96.89%	96.74%	98.89%	99.04%

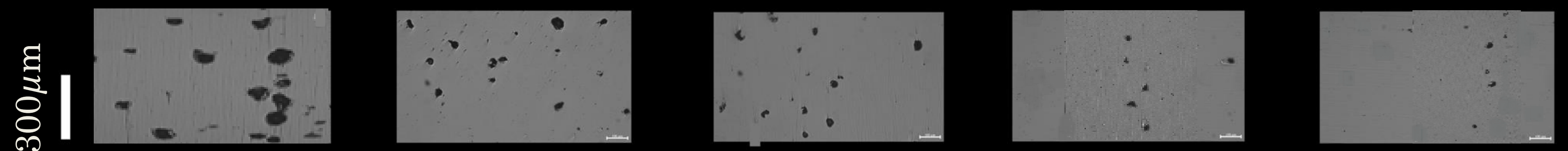


Image analysis Method	92.42%	97.18%	97.59%	98.76%	99.06%
Archimedes Method	97.27%	96.44%	96.47%	98.80%	99.09%

Result and Discussion

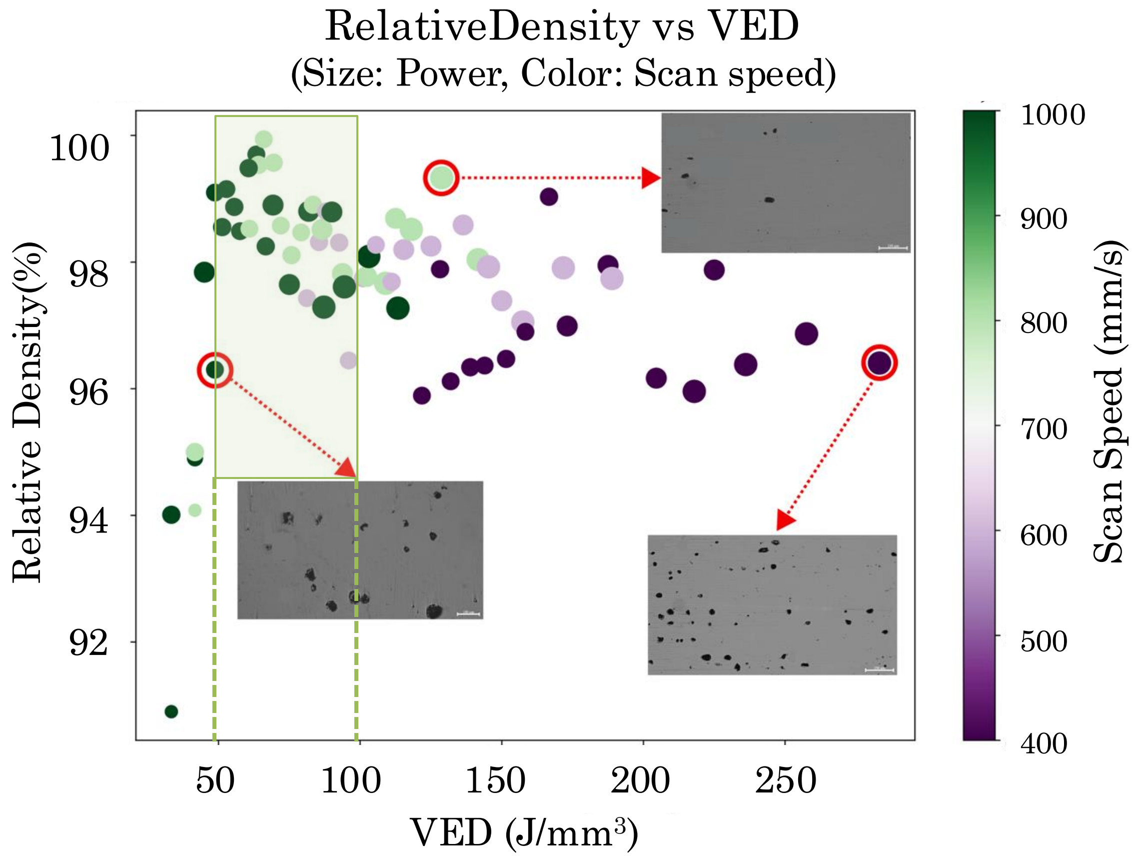
Volumetric **E**nergy **D**ensity (VED): 33 ~ 283 J/mm³

$$VED = \frac{P}{v.h.t}$$

- P → Power
- t → Layer Thickness
- h → Hatch Distance
- v → Scan Speed

Max. Relative Density: 99.9
P: 190 (W), v: 800 (mm/s), h: 0.12 (mm)

Min. Relative Density: 90.9
P: 100 (W), v: 1000 (mm/s), h: 0.1 (mm)

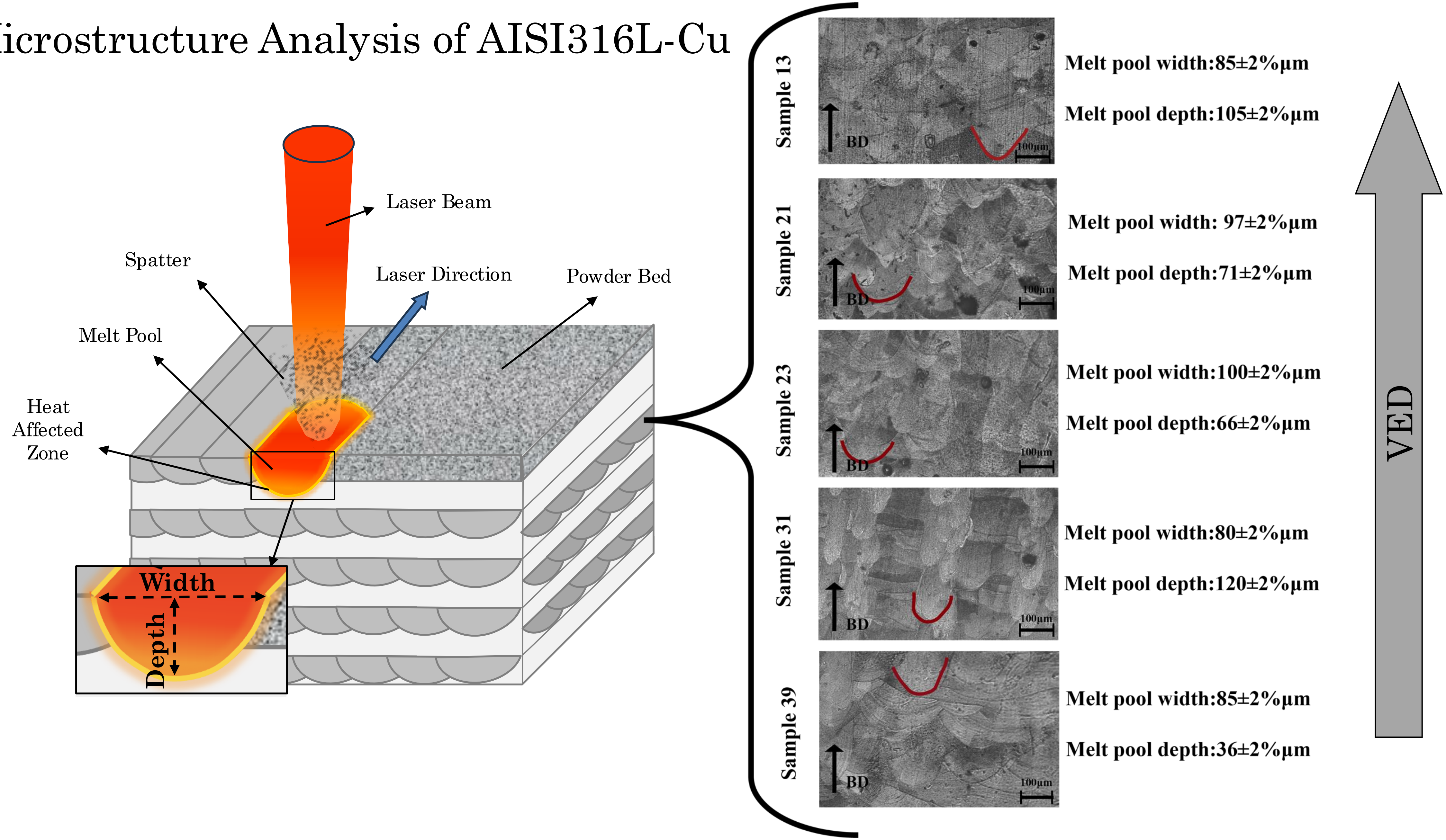


Applying **Machine Learning** models

Splitting the data into **training** and **testing** → Analysing the **three most effective** hyperparameters → Choosing the **best algorithm** → **Prediction**

Results and Discussion

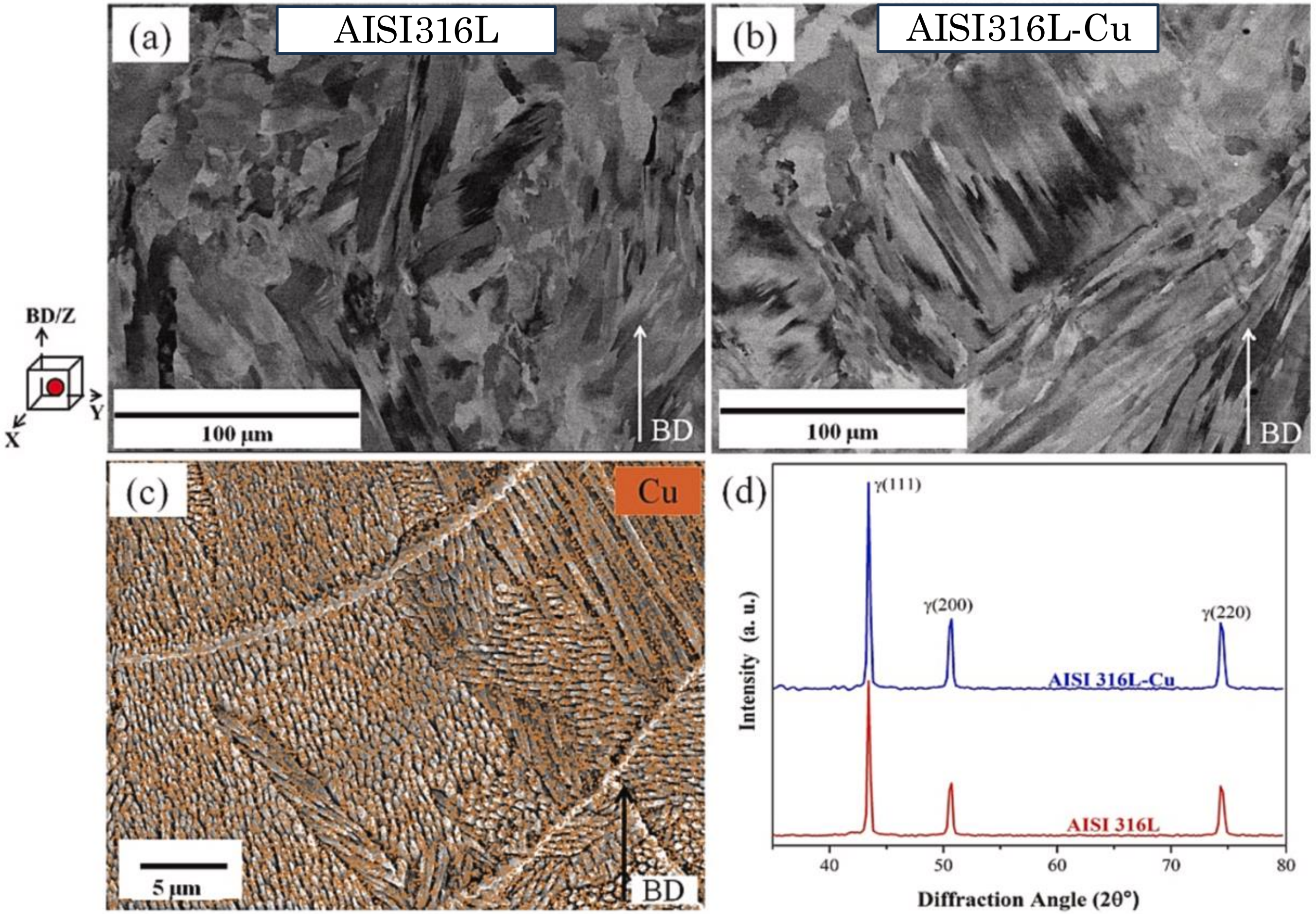
Microstructure Analysis of AISI316L-Cu



Results and Discussion

Microstructure Analysis

- Irregular grains formed due to rapid solidification in L-PBF.
- Cu fully dissolved into the austenitic phase with no segregation.
- Cu increases lattice distortion, reduces crystallite size, and boosts hardness.
- In-situ alloying with Cu improves mechanical properties.



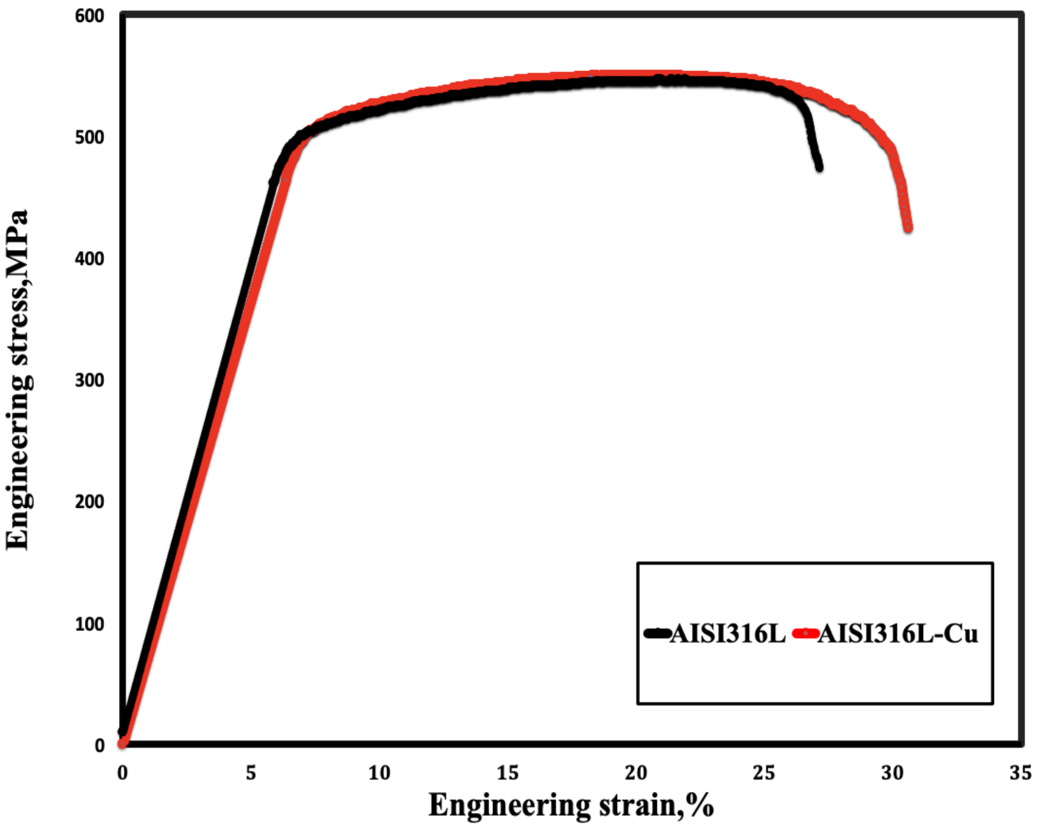
(e)

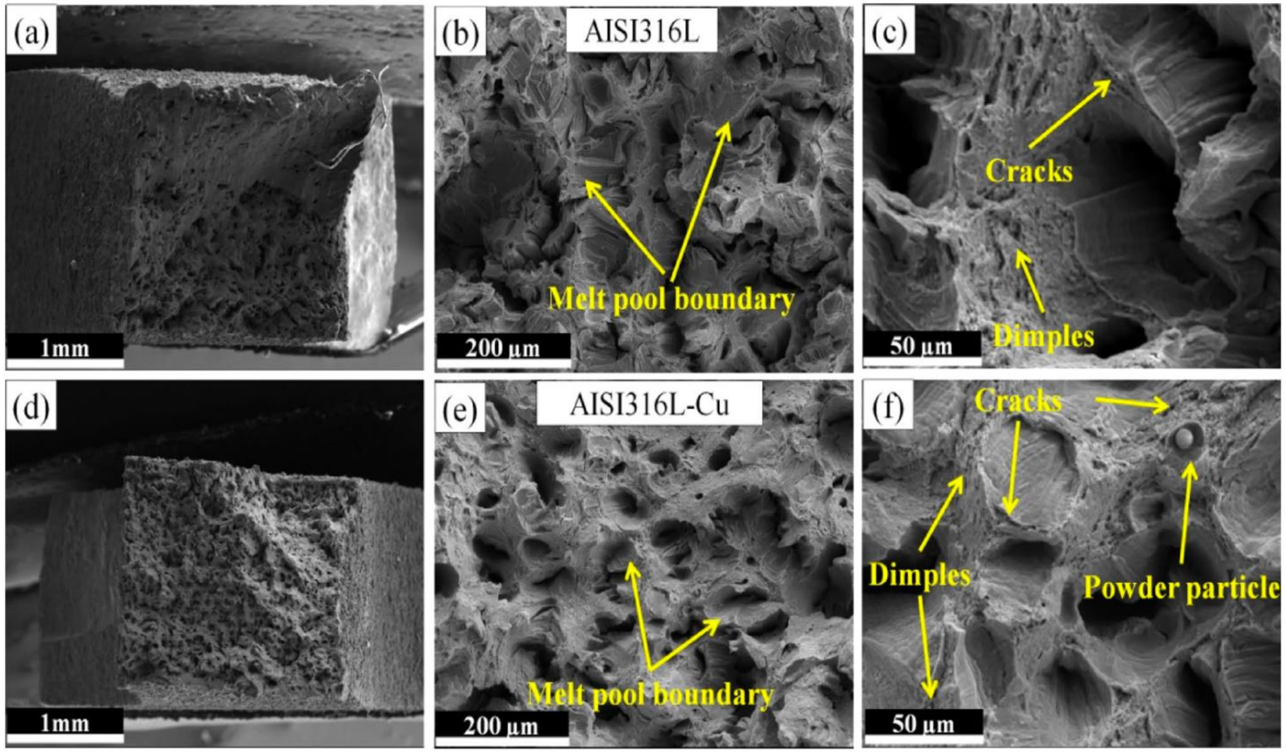
Sample	2 θ (°)	FWHM (rad)	Crystallite size (A°)	Micro strain (%)	Hardness (HV)	YS (MPa)	UTS (MPa)	Elongation (%)
LPBFed AISI316L	43.624	0.385	221	4.23	228±7	500±8	536±11	28.6±1.1
LPBFed AISI316L-Cu	43.452	0.475	147	6.37	245±8	510±7	558±6	30.4±1.4

Results and Discussion

Mechanical Properties

Cu addition strengthens AISI316L, improving its mechanical properties compared to pure AISI316L.





Conclusions

1. SVR was the best model for predicting L-PBF process parameter defect content relationship, achieving high accuracy with an 80/20 data split and low error rates.

2. Higher energy densities create deeper melt pools, while lower energy densities produce shallower melt pools.

3. According to the XRD analysis, the copper atom dissolves into iron, forming a complete austenitic structure under the L-PBF process.

4. Tensile test results show that even a small copper addition slightly impacts the mechanical properties of as-built AISI 316L.

Any Question!

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