Development and processability of AISI S2 tool steel by Laser Powder Bed Fusion

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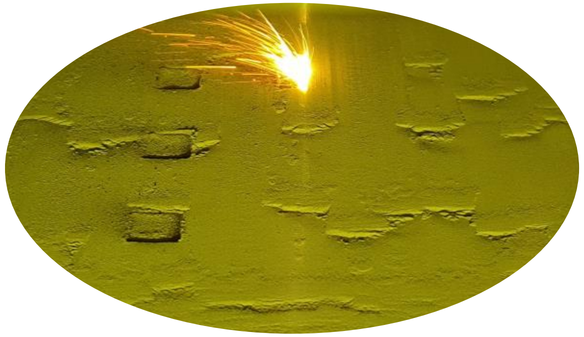
Introduction

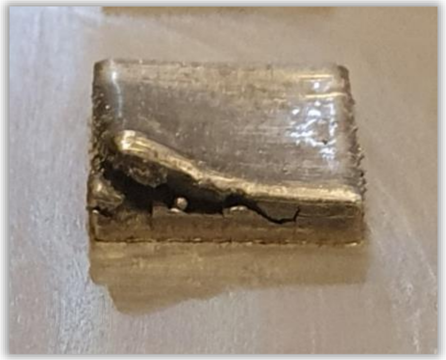
Tool steels are used in applications such as cutting, forming, shearing, stamping.

Conventional manufacturing of tool steels are:
casting, electroslag remelting or powder metallurgy.

Zumofen et al., 2020



Laser Powder Bed Fusion is becoming attractive for the possibility of producing complex shape implementing internal cooling channels.



Tool steels by LPBF are difficult to process due to the complex chemical compositions (C, Cr, Mo, V, W, Co…) leading to defects within the final part (cracks, lack of fusion, key-hole porosities…).

This study aims to provide the basis for understanding the **PROCESSABILITY** and **MICROSTRUCTURE** of tool steel AISI S2.

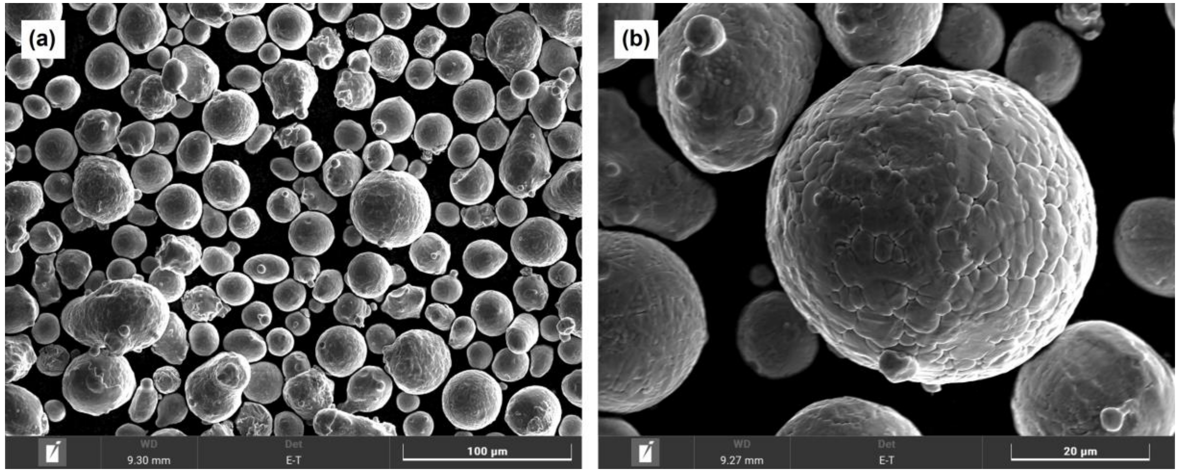
Materials and Methods

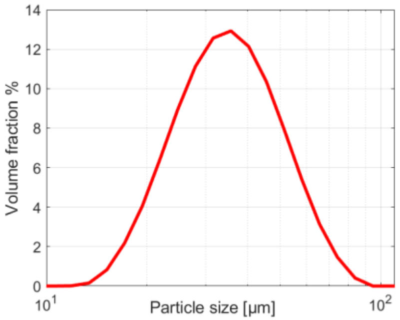
AISI S2 Tool Steel

wt%

Fe	C	Si	Mo	Mn
Bal.	0.49	1.2	0.6	0.6

Powders obtained by Gas Atomization





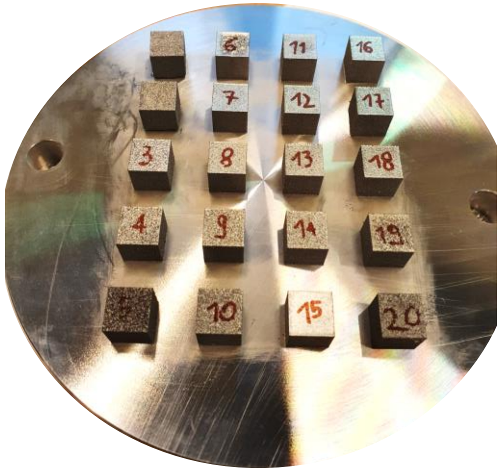
D(0.1) = 21 µm
D(0.5) = 32 µm
D(0.9) = 51 µm

Aconity MIDI

Laser Powder Bed Fusion machine

20 cubes

10 x 10 x 10 mm³



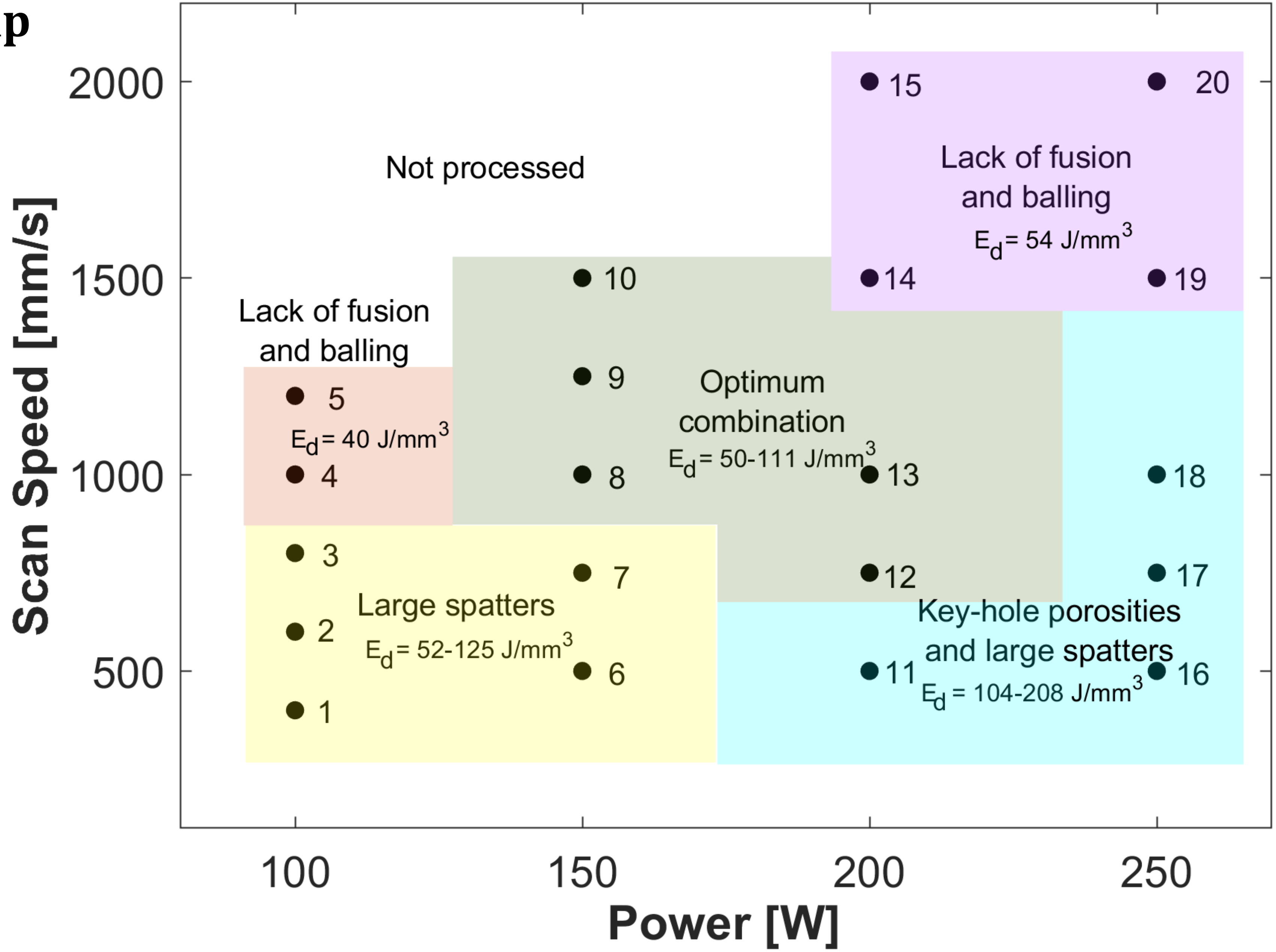
Parameters

- **<u>Power</u>** (P, 100 – 250 W)
- **<u>Scan speed</u>** (v_s, 400 – 2000 mm/s)
- Layer Thickness (t, 30 µm)
- Hatch Spacing (h, 80 µm)
- Laser beam size (80 µm)
- Scan Strategy (Bidirectional 90°)
- Preheating NO

Volumetric Energy Density

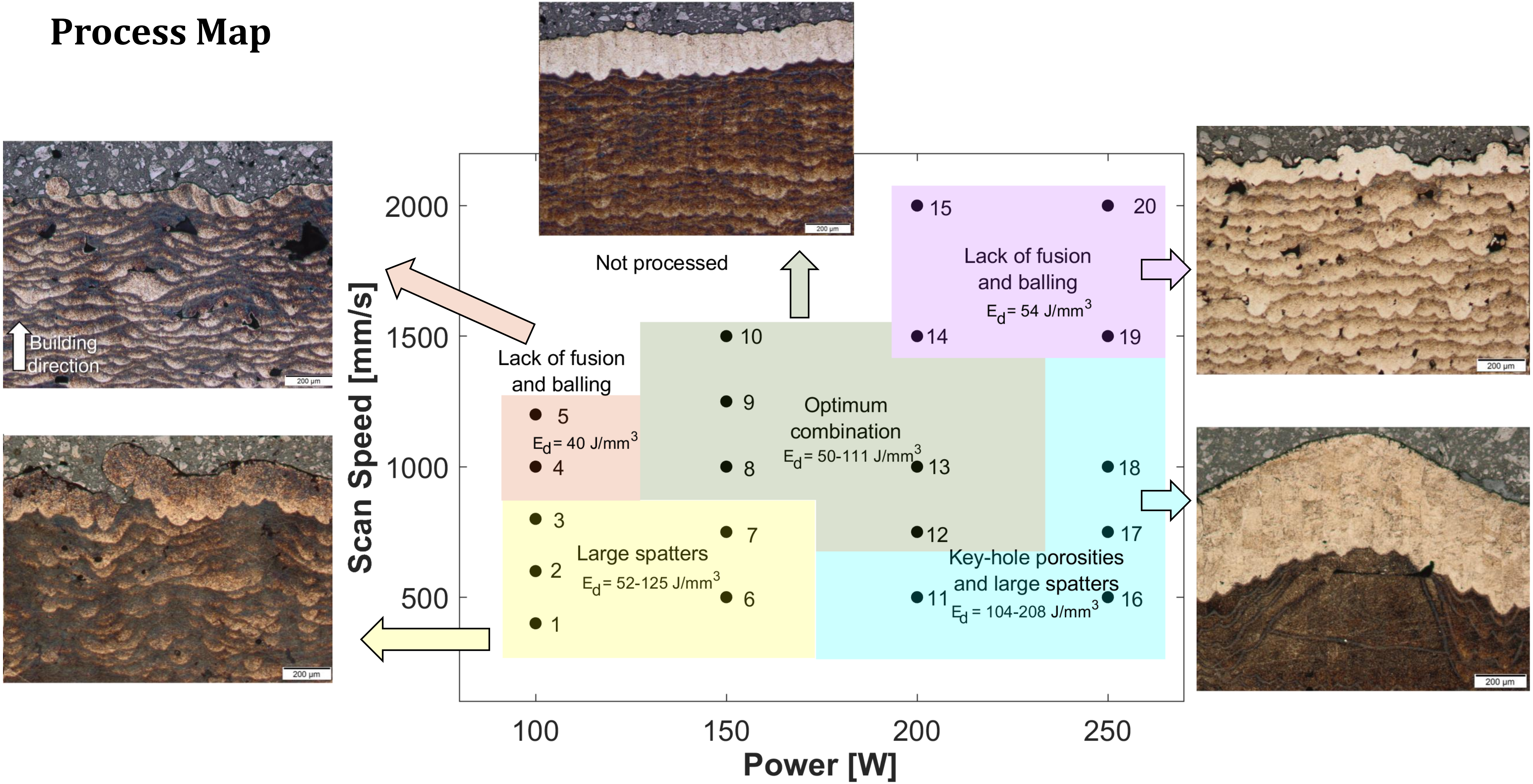
$$E_d = \frac{P}{t \times h \times v_s} \quad [\mathrm{J/mm^3}]$$

Process Map

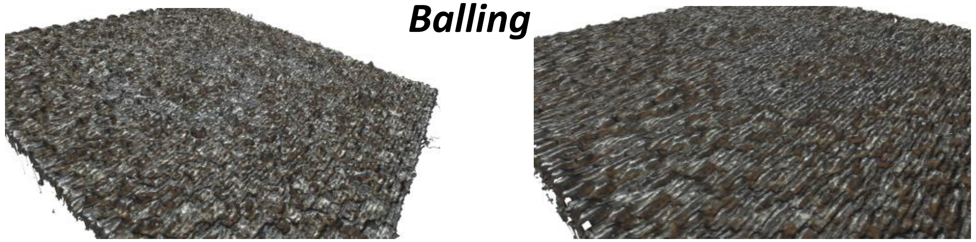


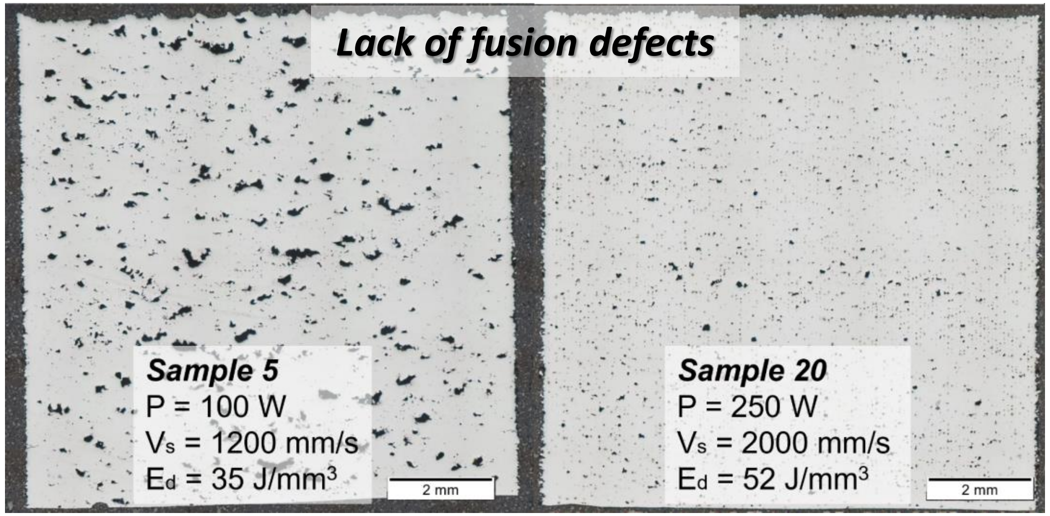
2000
1500
1000
500
Scan Speed [mm/s]
100
150
200
250
Power [W]
Not processed
Lack of fusion and balling
E_d= 40 J/mm^3
Optimum combination
E_d= 50-111 J/mm^3
Lack of fusion and balling
E_d= 54 J/mm^3
Large spatters
E_d= 52-125 J/mm^3
Key-hole porosities and large spatters
E_d = 104-208 J/mm^3
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

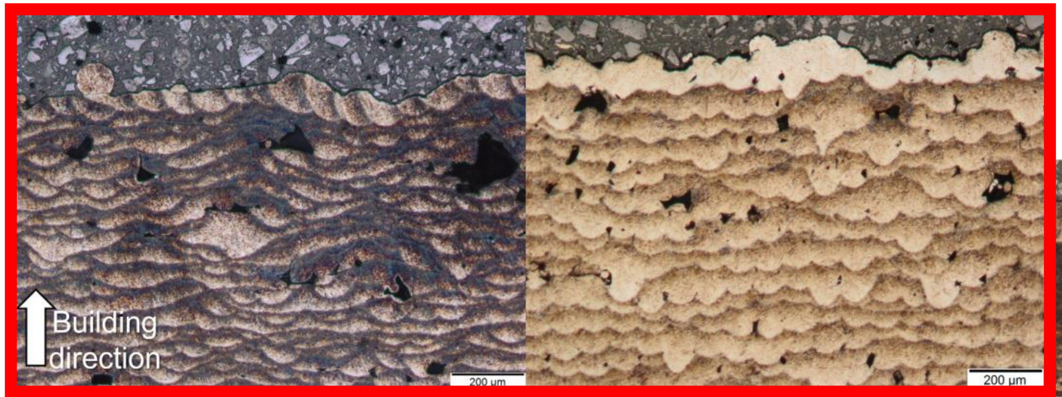
Process Map

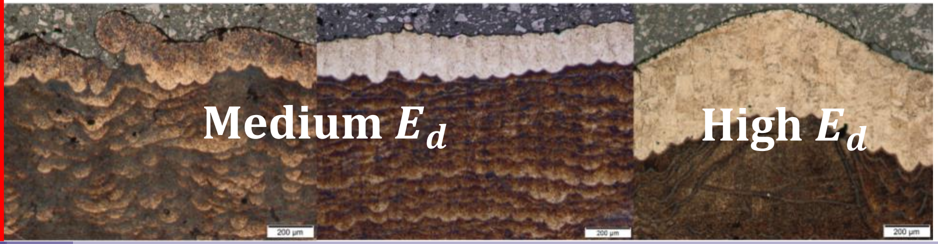

Building direction
200 µm
Not processed
Lack of fusion and balling
E_d= 54 J/mm^3
15
20
14
19
Lack of fusion and balling
E_d= 40 J/mm^3
5
4
10
9
8
Optimum combination
E_d= 50-111 J/mm^3
13
12
18
17
3
2
1
7
6
Large spatters
E_d= 52-125 J/mm^3
Key-hole porosities and large spatters
E_d = 104-208 J/mm^3
11
16
Scan Speed [mm/s]
2000
1500
1000
500
100
150
200
250
Power [W]

Process Map – Low E_d





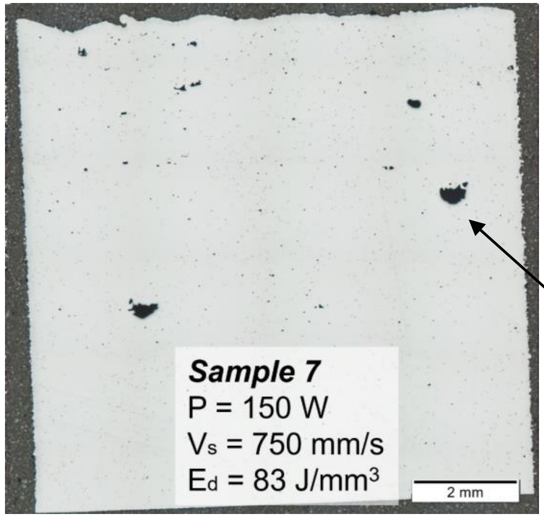




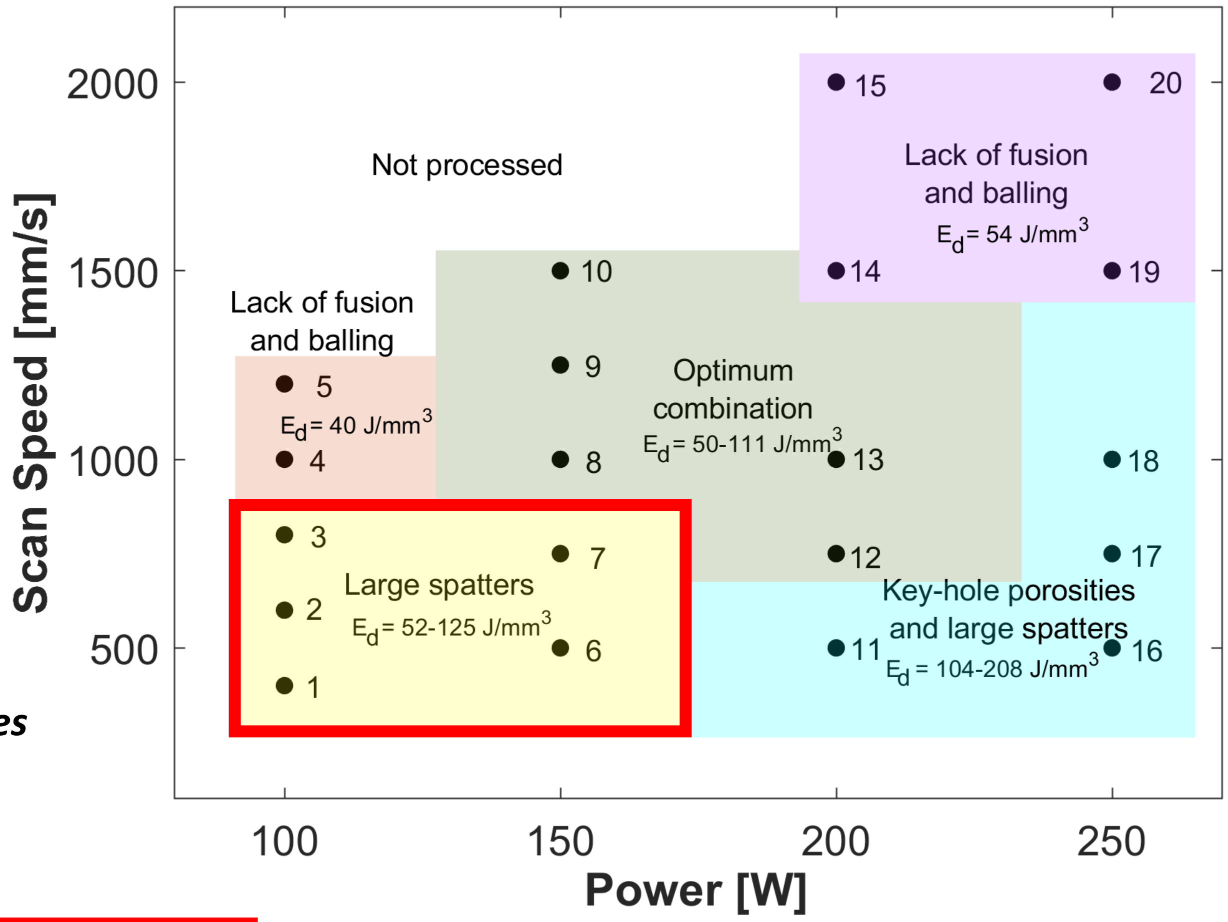
Process Map – Medium E_d

Interrupted printing - Spatters on surface

Irregular surface

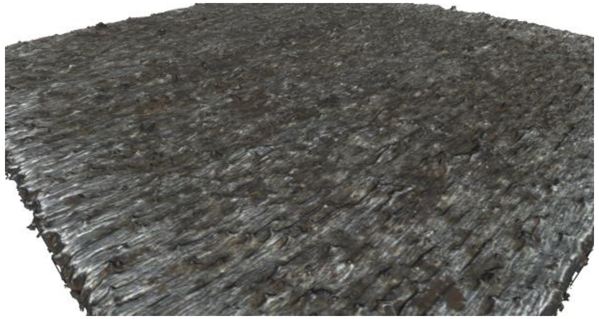


Large porosities

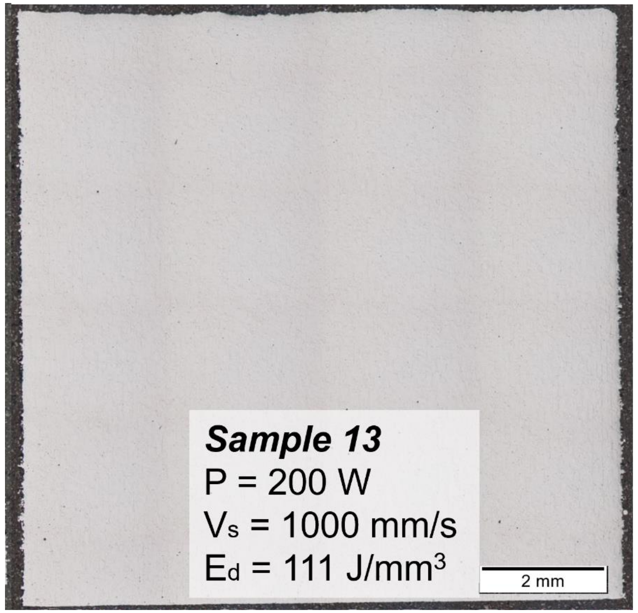


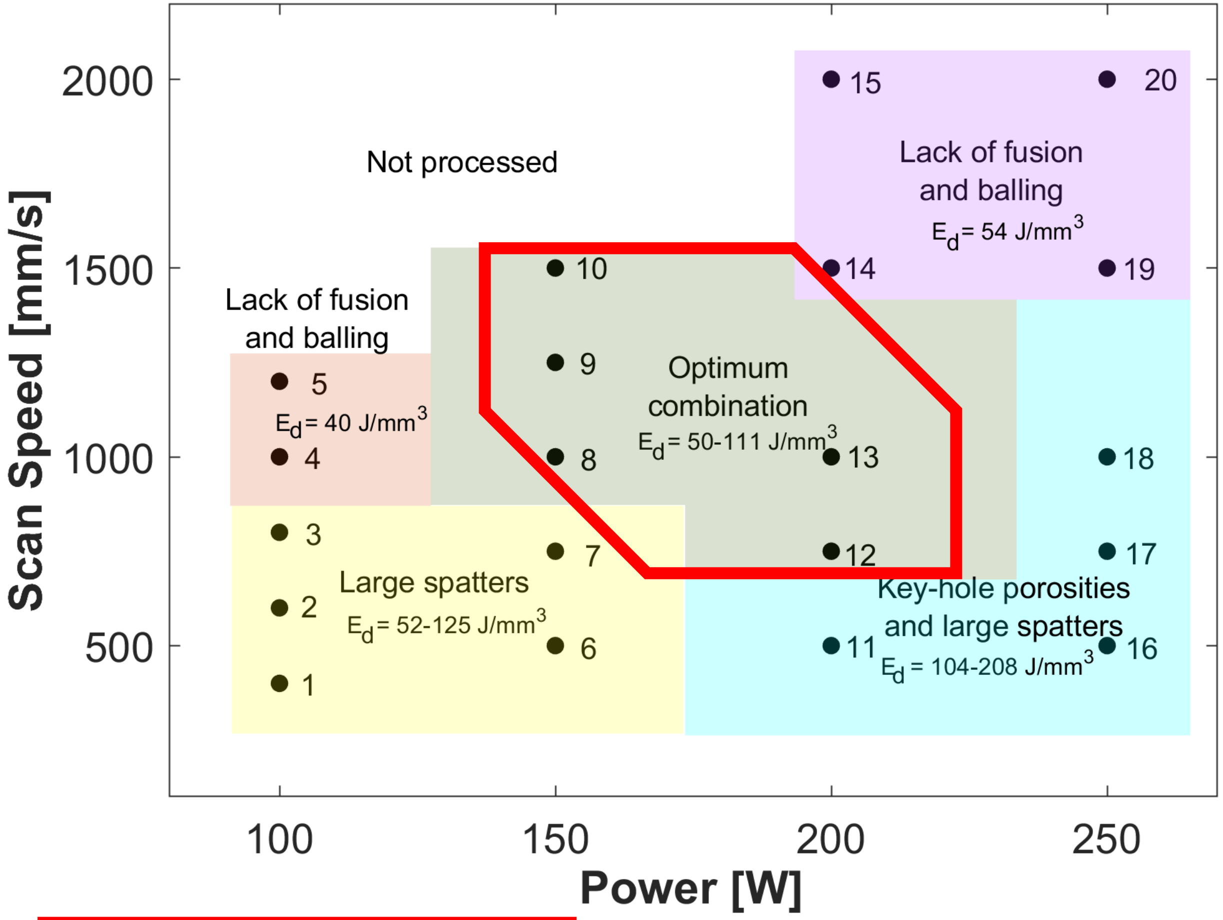
Process Map – Medium E_d

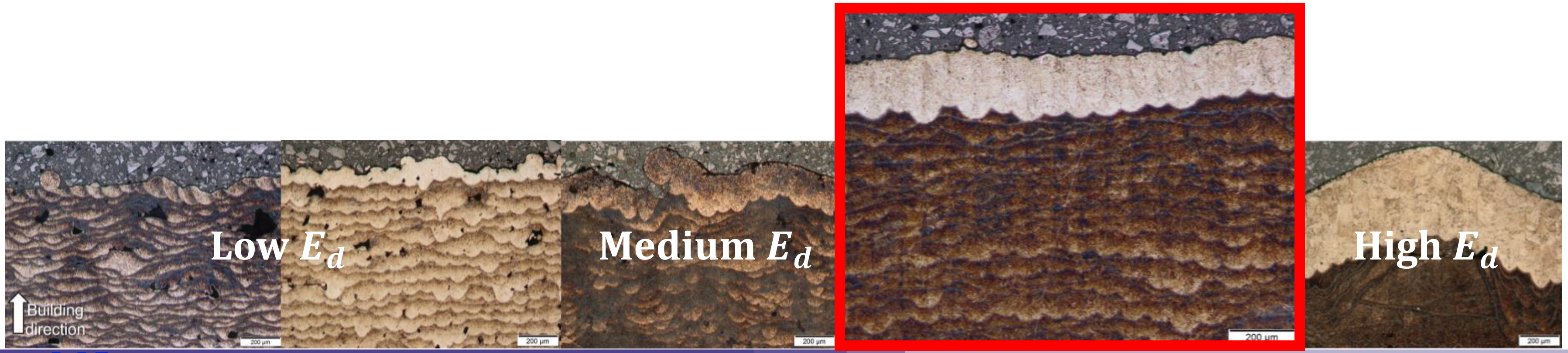
Regular surface



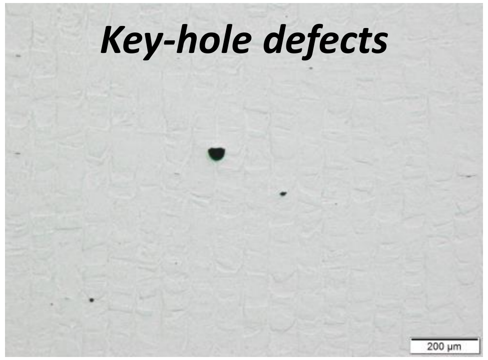
Fully dense, defect – free sample

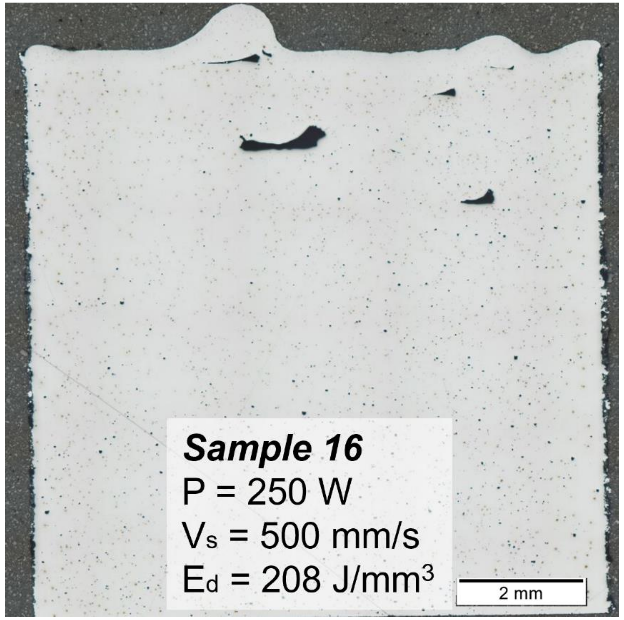


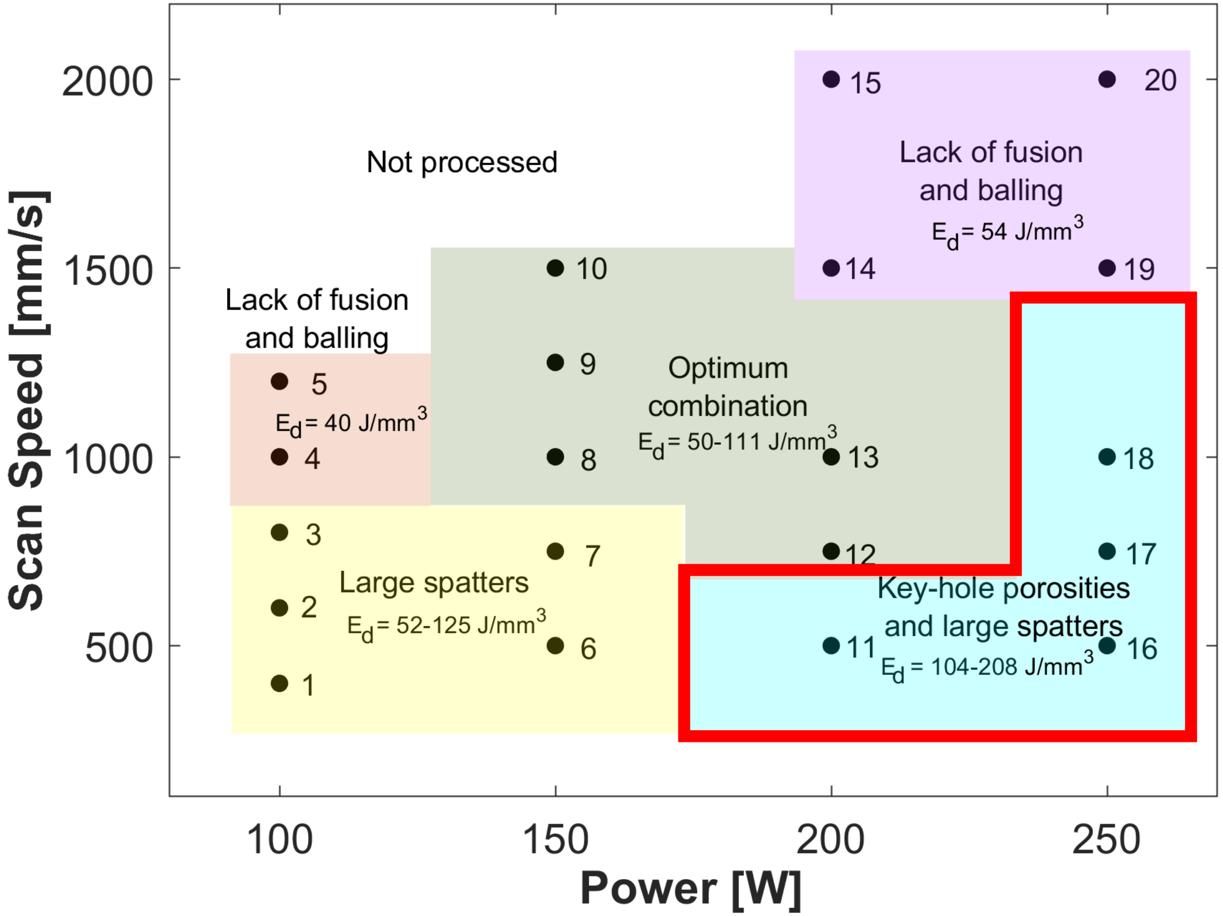


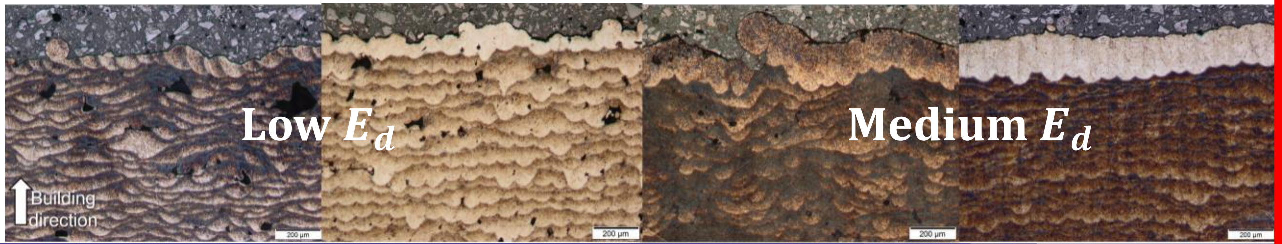


Process Map – High E_d

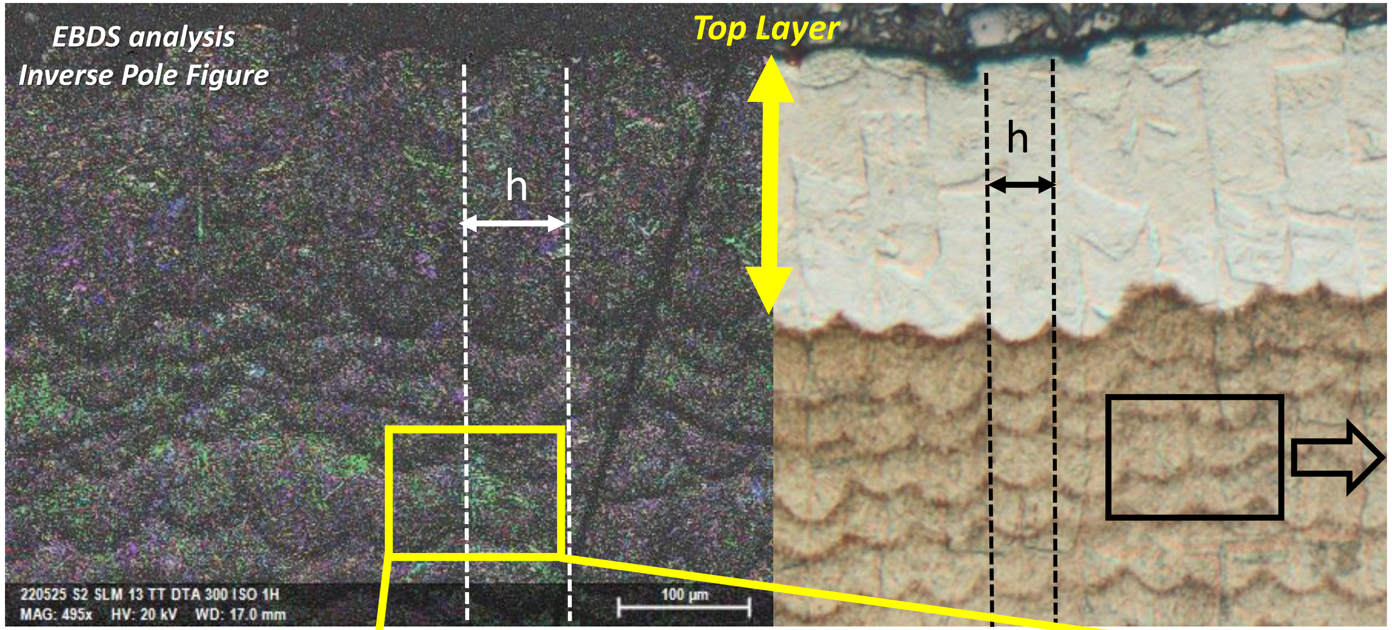






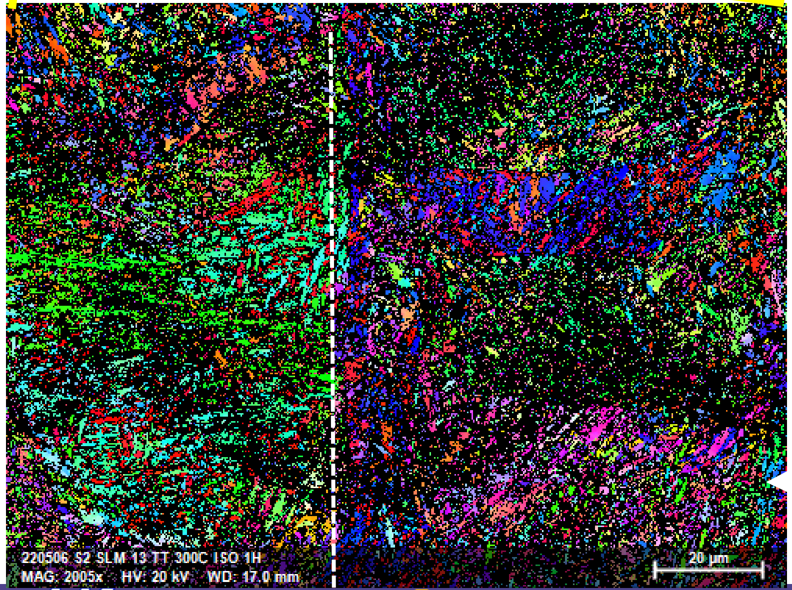


Microstructure and in-situ Thermal Treatments

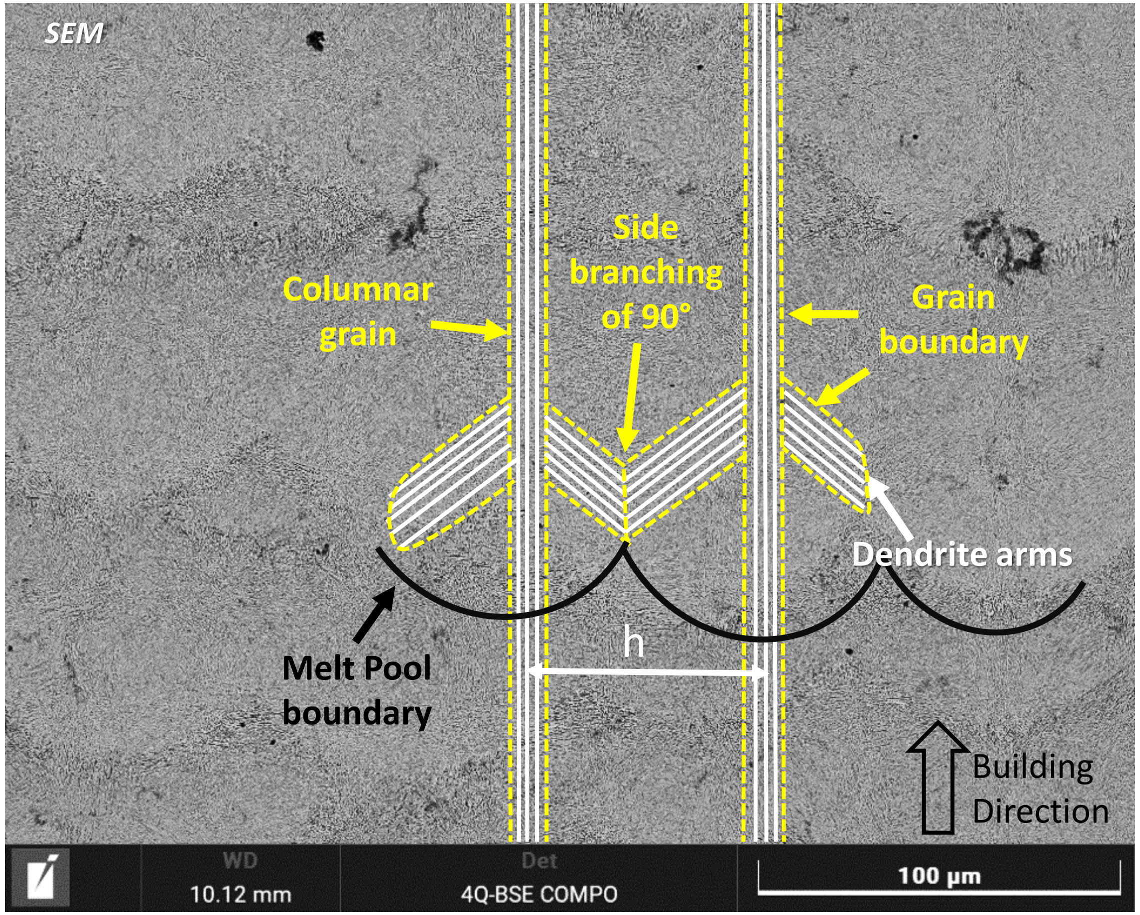


Optical micrograph after ecthing with Nital 3%

EBDS analysis Inverse Pole Figure

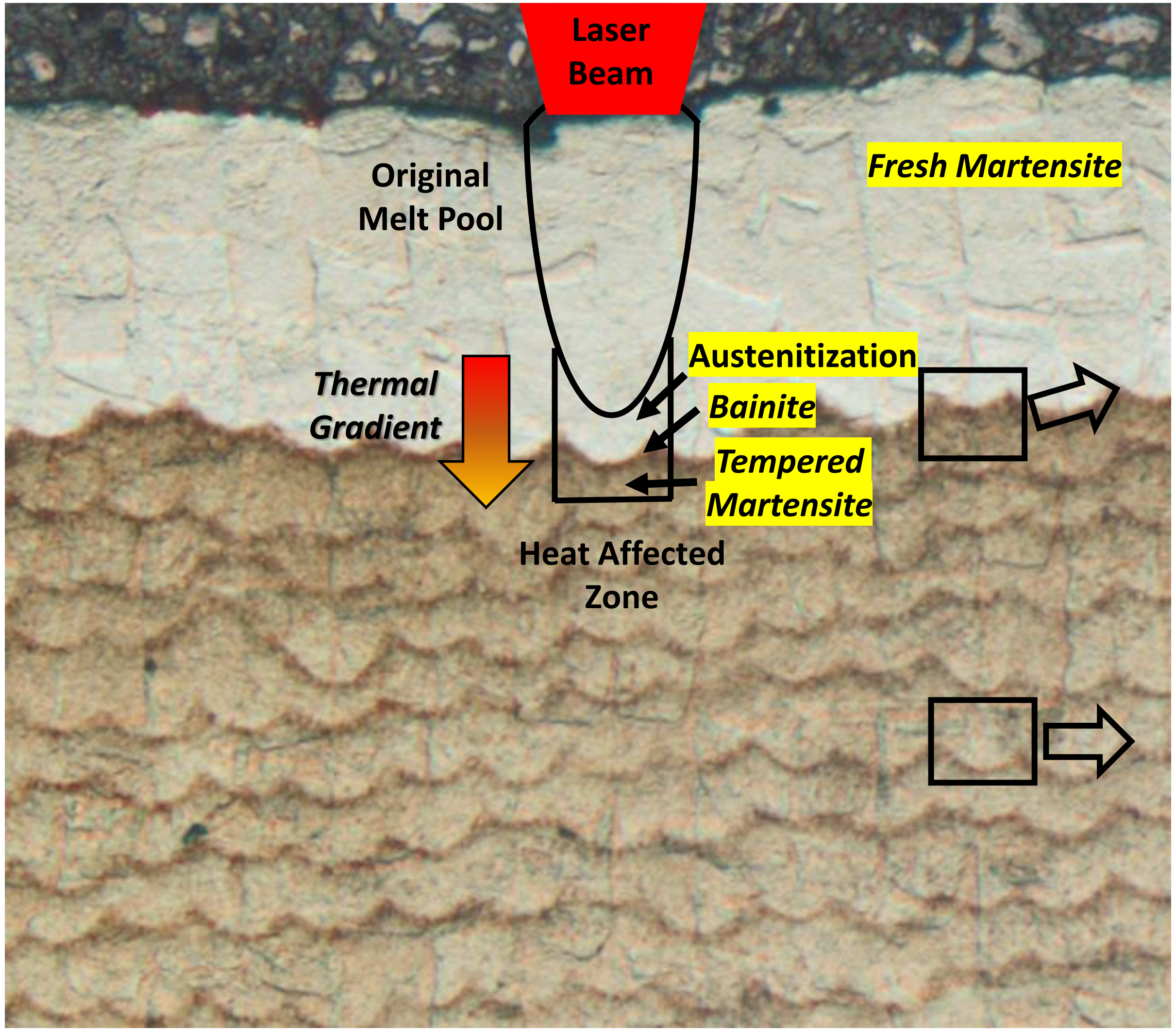


Continuous epitaxial growth

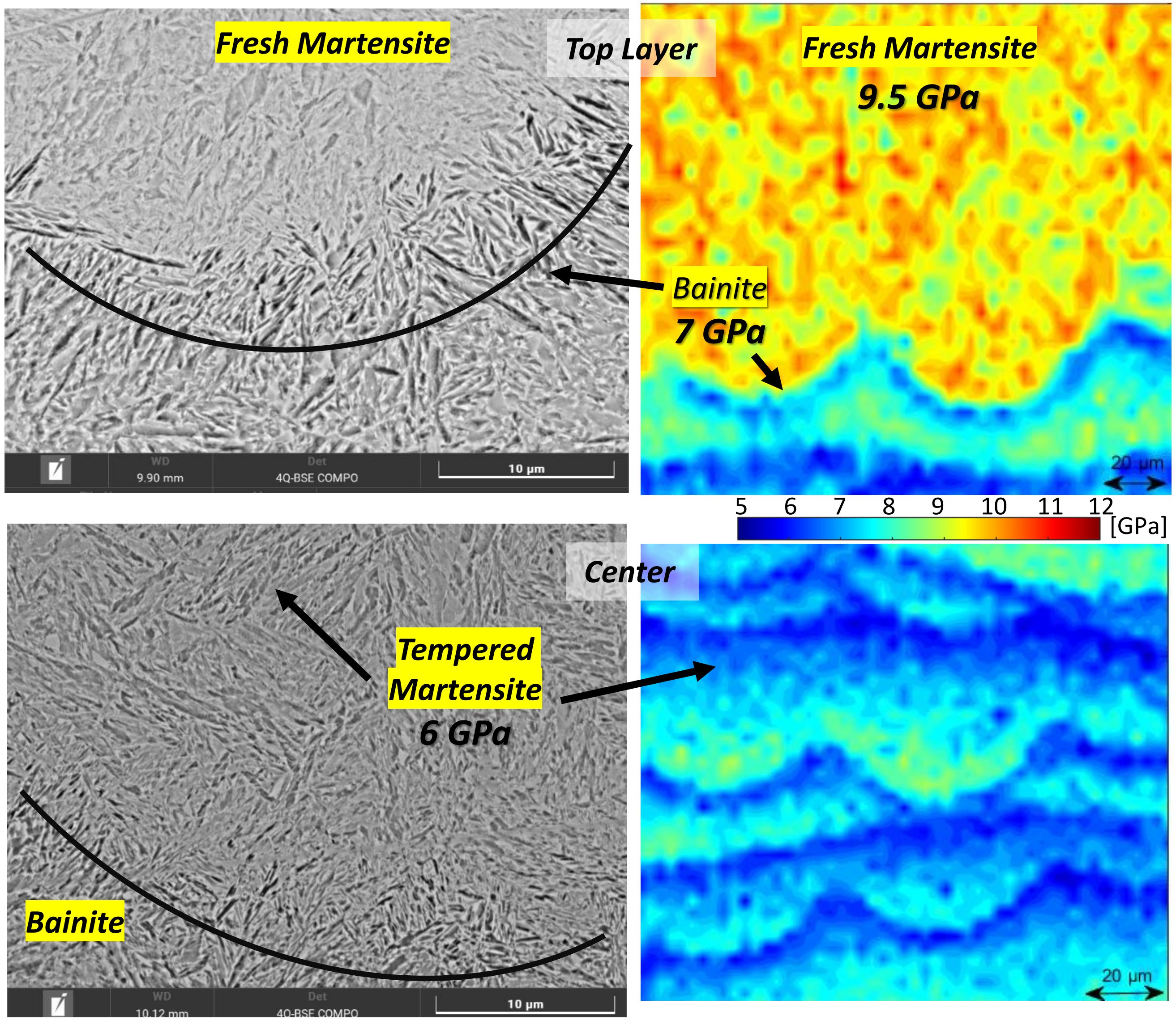


Microstructure and in-situ Thermal Treatments

Optical micrograph after ecthing with Nital 3%



SEM *NanoHardness Grid*



Conclusions

Processability

- Medium v_s (750 – 1000 mm/s) and P (200 W) (Ed ~ 97 J/mm^3) allow to achieve fully dense and defect-free parts;
- High v_s (1000 – 2000 mm/s) and low E_d (35 – 69 J/mm^3) cause lack of fusion and balling, regardless of the P applied;
- Low v_s (400 – 1000 mm/s) and mostly high E_d (69 – 208 J/mm^3) cause large spatters and key-hole porosities, regardless of the P applied;

Microstructure

- Epitaxial grains growth is observed within the microstructure;
- Fresh martensite, bainite and tempered martensite are observed. In-situ thermal treatments during the process are responsible for the change in the microstructure;

Thanks for your attention

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