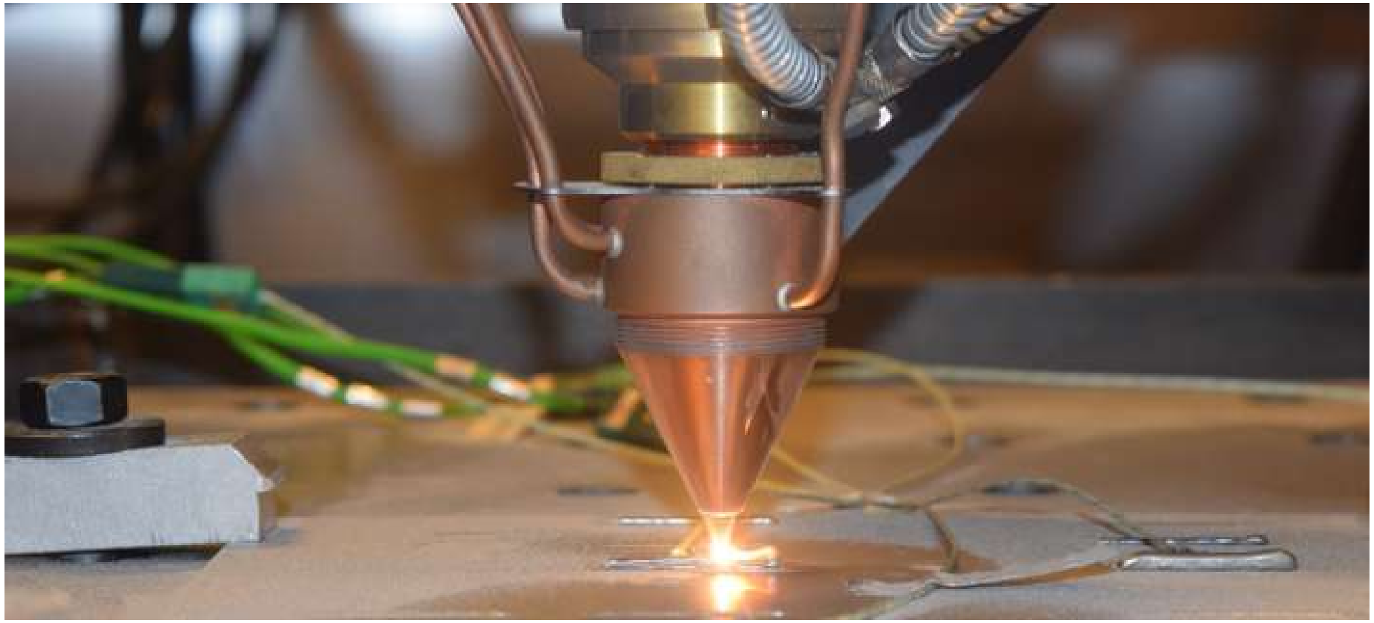
Influence of Process Parameters on Microstructure using Laser Metal Powder Deposition



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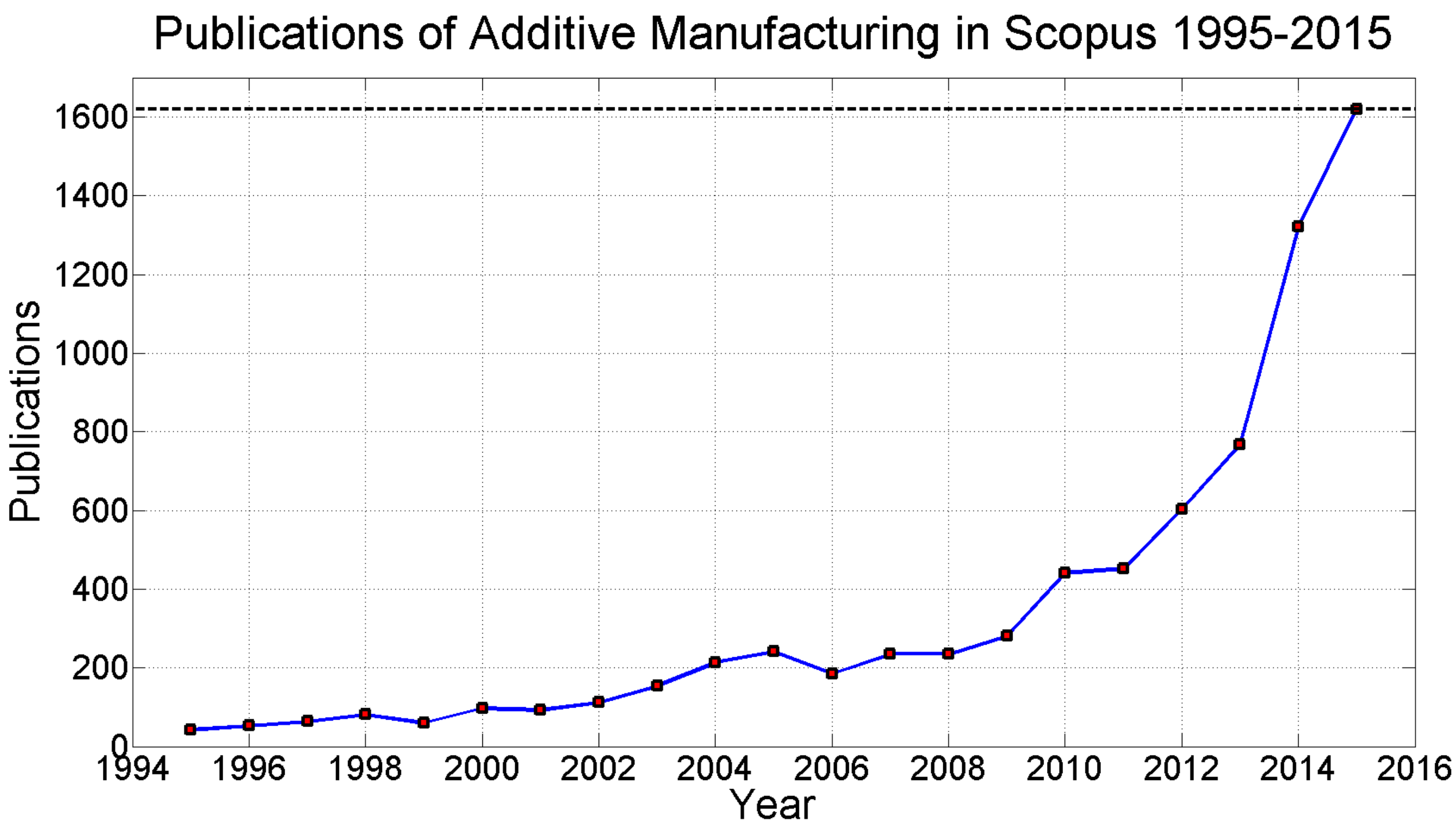
AM publications 1995-2015



Scopus.com. (2016). "Analyze Results - Additive Manufacturing." Retrieved 2016-08-19, from http://www.scopus.com.

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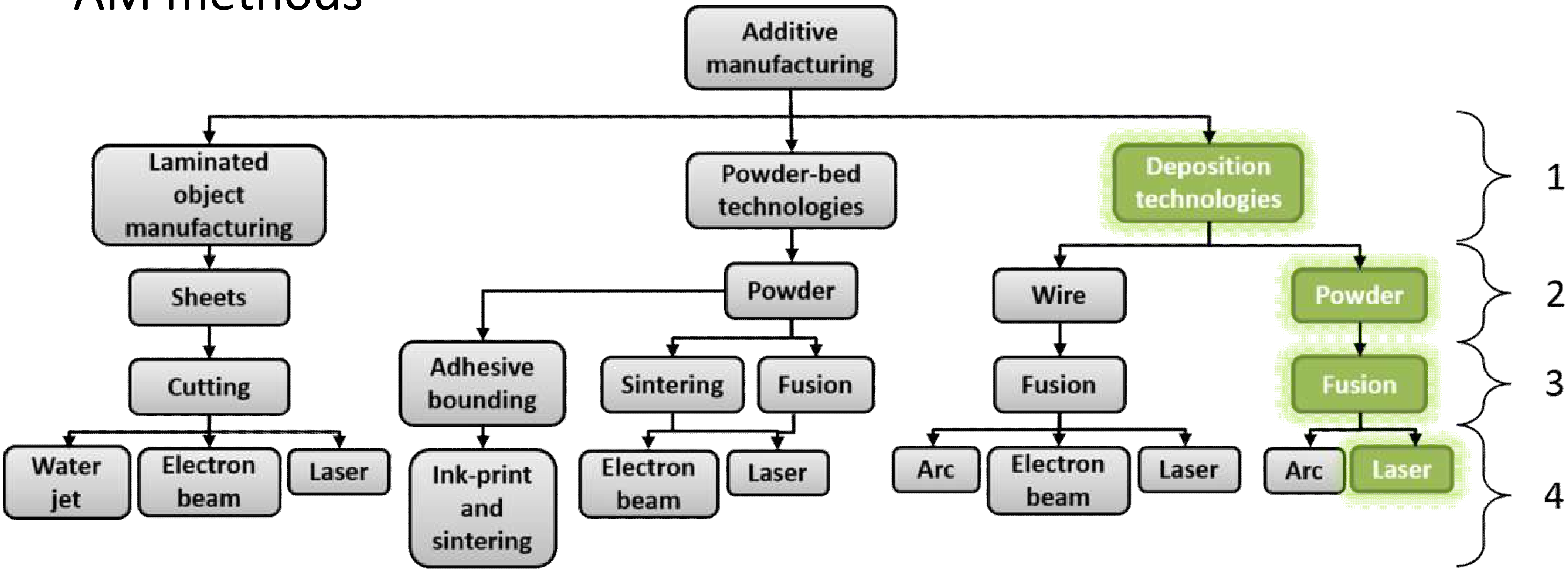
AM methods



Antonysamy, A. A. (2012). "Microstructure, texture and mechanical property evolution during additive manufacturing of Ti6Al4V alloy for aerospace applications" Ph.D. Thesis, University of Manchester.

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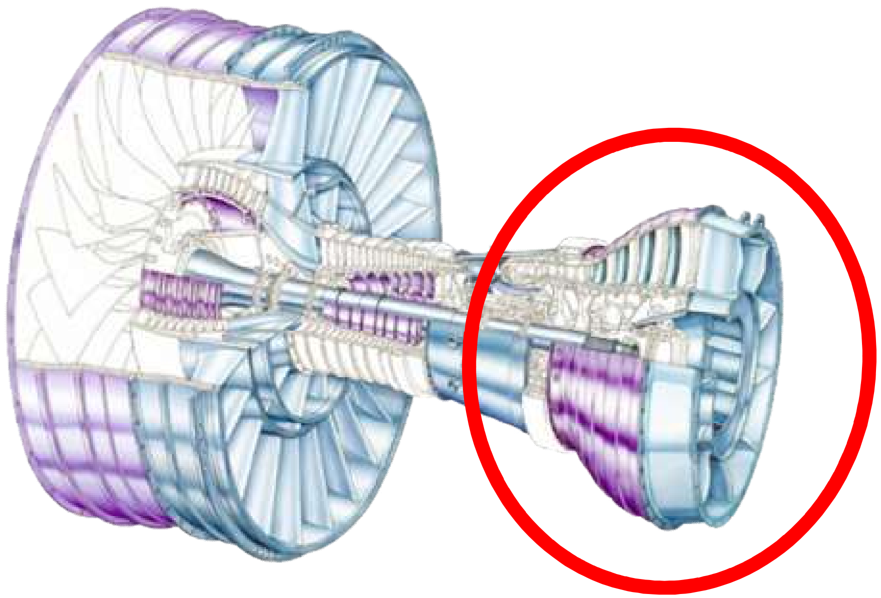
Material

- Ni-Fe based superalloys - Alloy 718
  - FCC (γ) gamma matrix
  - Secondary phases
    - γ' Gamma prime
    - γ'' Gamma double prime
    - δ delta phase
    - Laves phase
    - Carbides
      - MC
      - M_6C
      - $M_{23}C_6$



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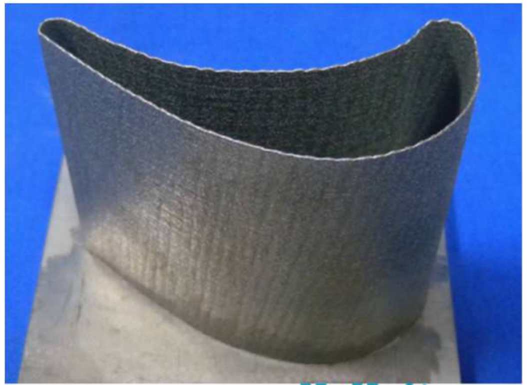
Applications in aero industry

- Direct connection to the aero industry with application such as
  - Repair method for sensitive parts
    - Turbine blades
    - Manifolds
  - Add on features to jet engine
    - Stiffeners
  - Refurbish end of life products
  - Manufacture turbine blades



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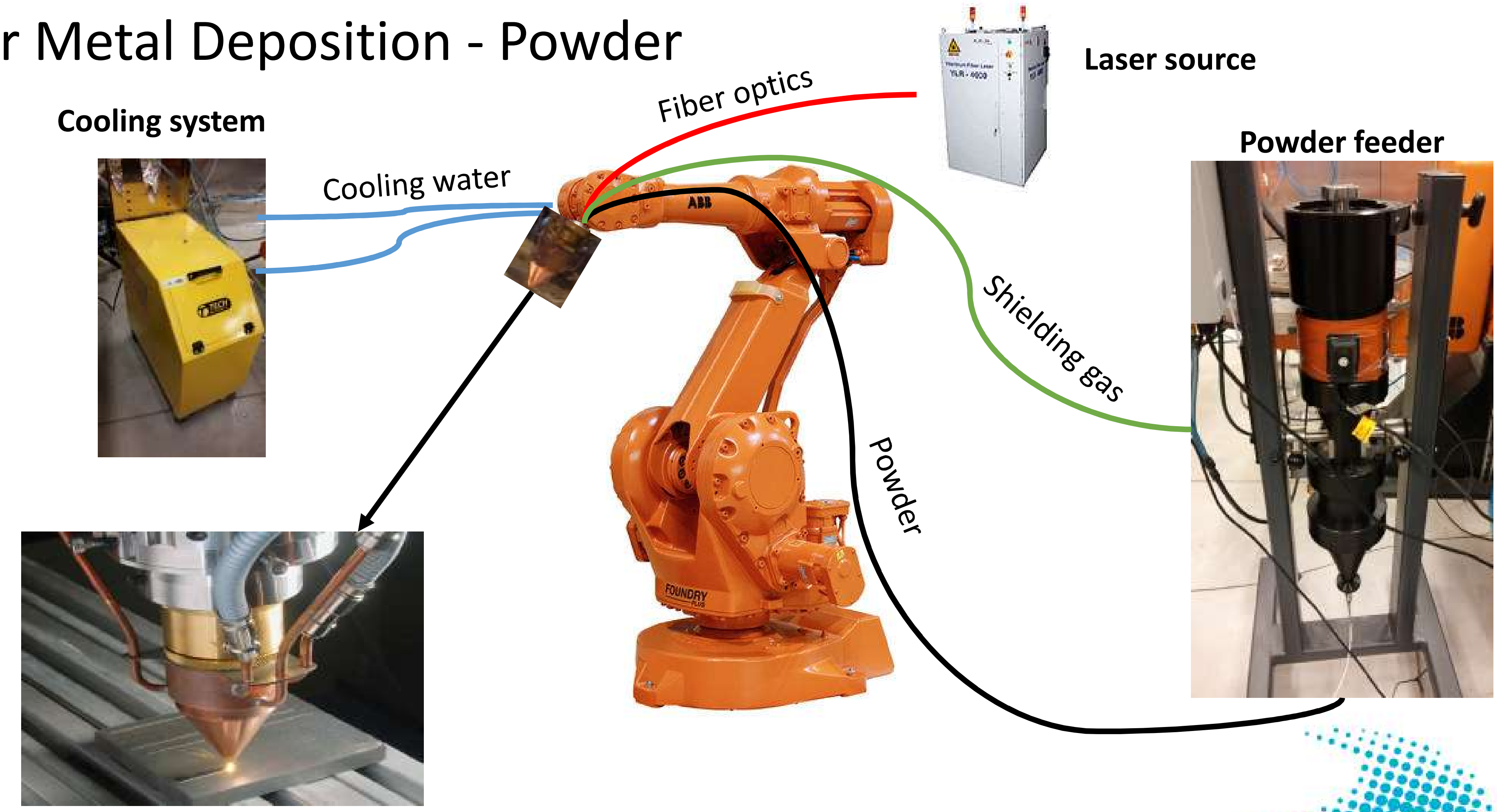
Laser Metal Deposition - Powder



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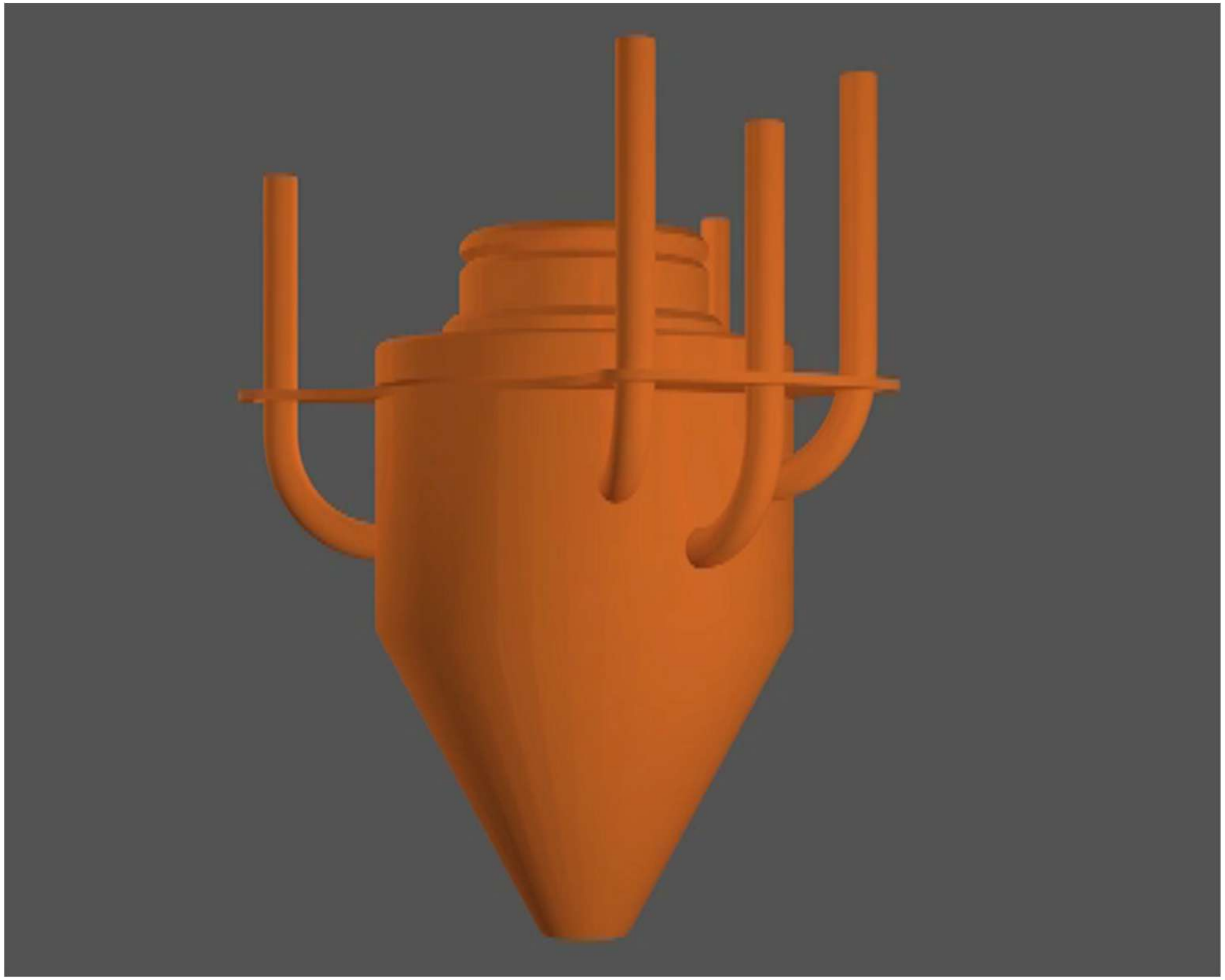
The LMD process



Pre-study evaluating the most influential process parameters

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Effect of process parameters on dimensional characteristics

Process parameters

- Laser power
- Powder feeding rate
- Scanning speed
- Laser standoff
- Powder standoff
- Shielding gas flow

Dimensional characteristics

- Height of deposit
- Width of deposit
- Straightness of top surface

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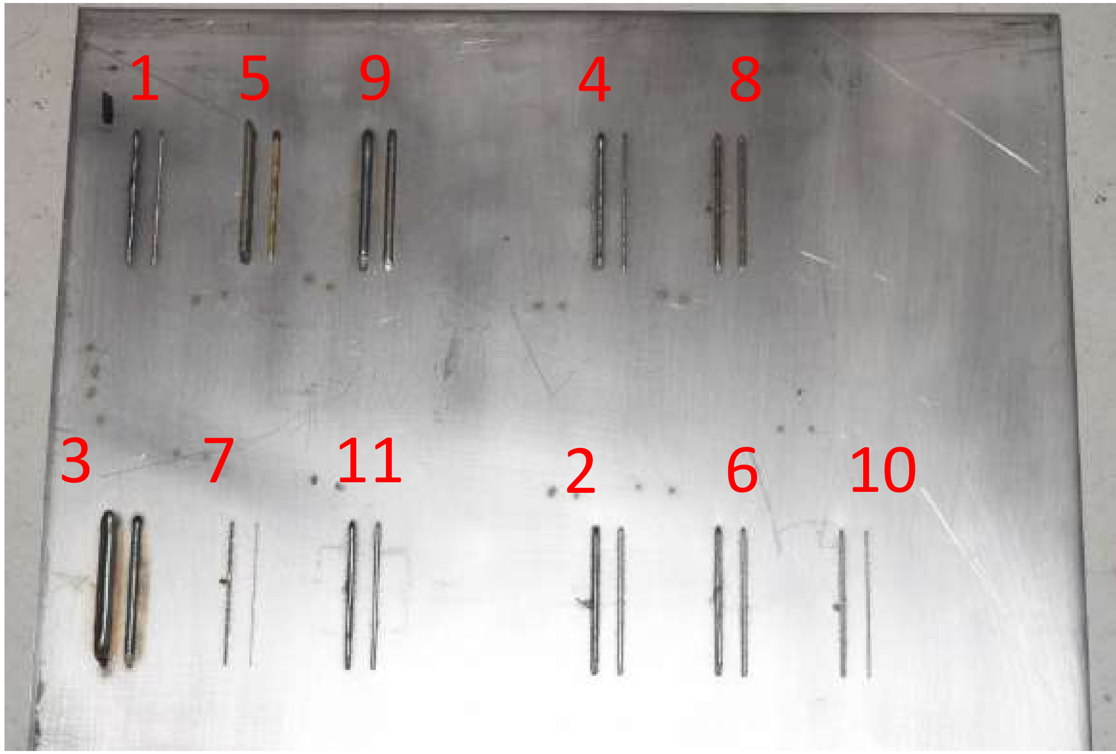
Placket Burman DOE – which are the most influential process parameters?

Laser power	400 to 1000 W
Scanning speed	5 to 30 mm/s
Powder feeding rate	2 to 10 g/min
Shield gas flow	8 to 15 L/min
Powder standoff	-1 to 1 mm
Laser stand off	5 to 10 mm

- 8 parameter sets
  - 3 mid-points replicates
- Distribution of deposits to prevent heat concentration



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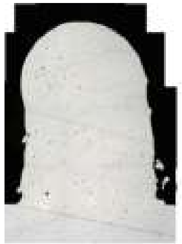
Results – Width and Height deposit

1.

2.



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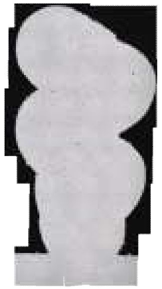
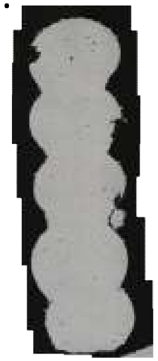


4.

5.



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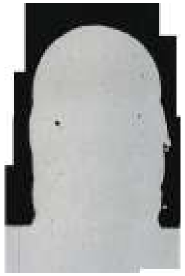

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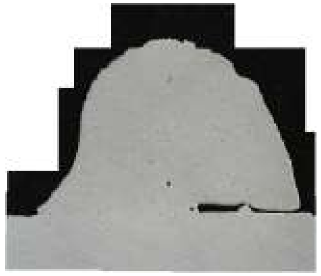
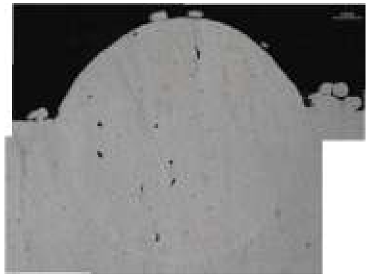


NOT TO SCALE!

8.



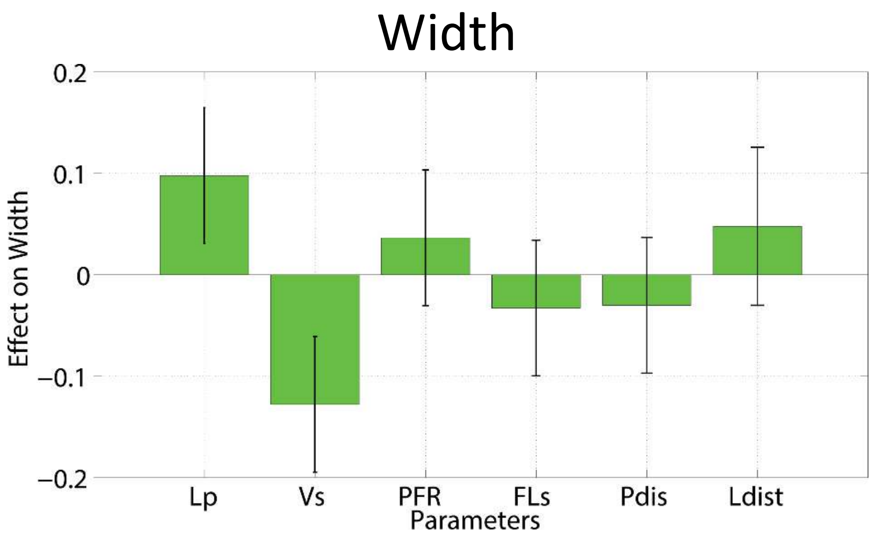
9.

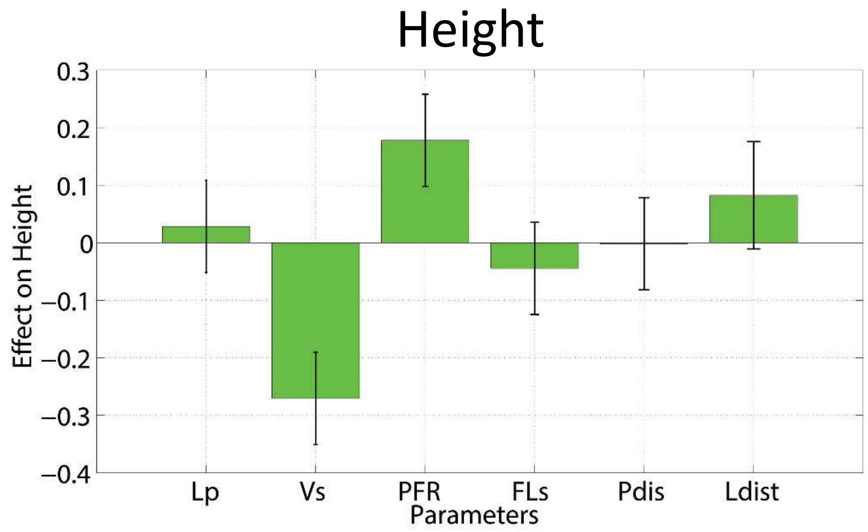
10.

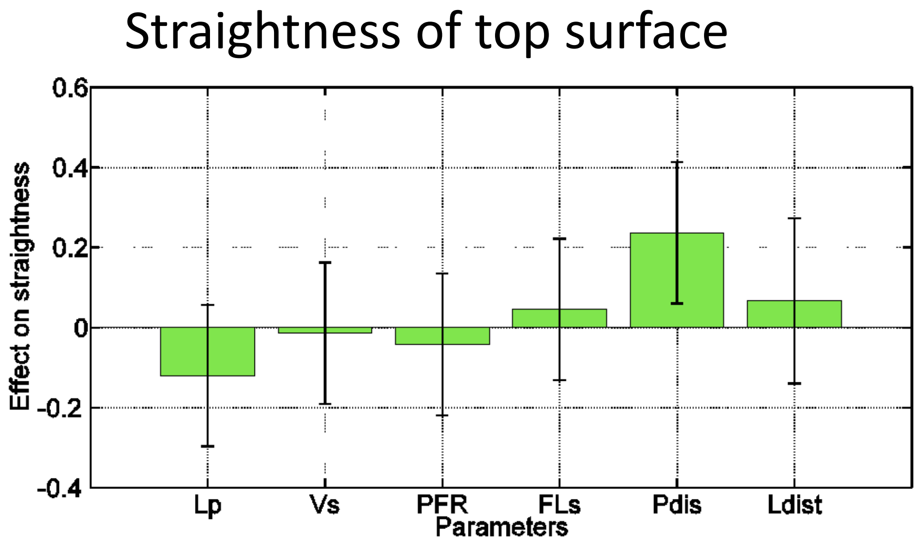
11.

Parameter set	1	2	3	4	5	6	7	8	9	10	11
Width (mm)	1.2	1.4	2.1	1.0	1.8	1.2	0.5	1.0	2.5	0.7	1.2
Height (mm)	0.5	0.5	1.9	0.5	1.5	0.5	0.1	0.1	0.6	0.2	0.5

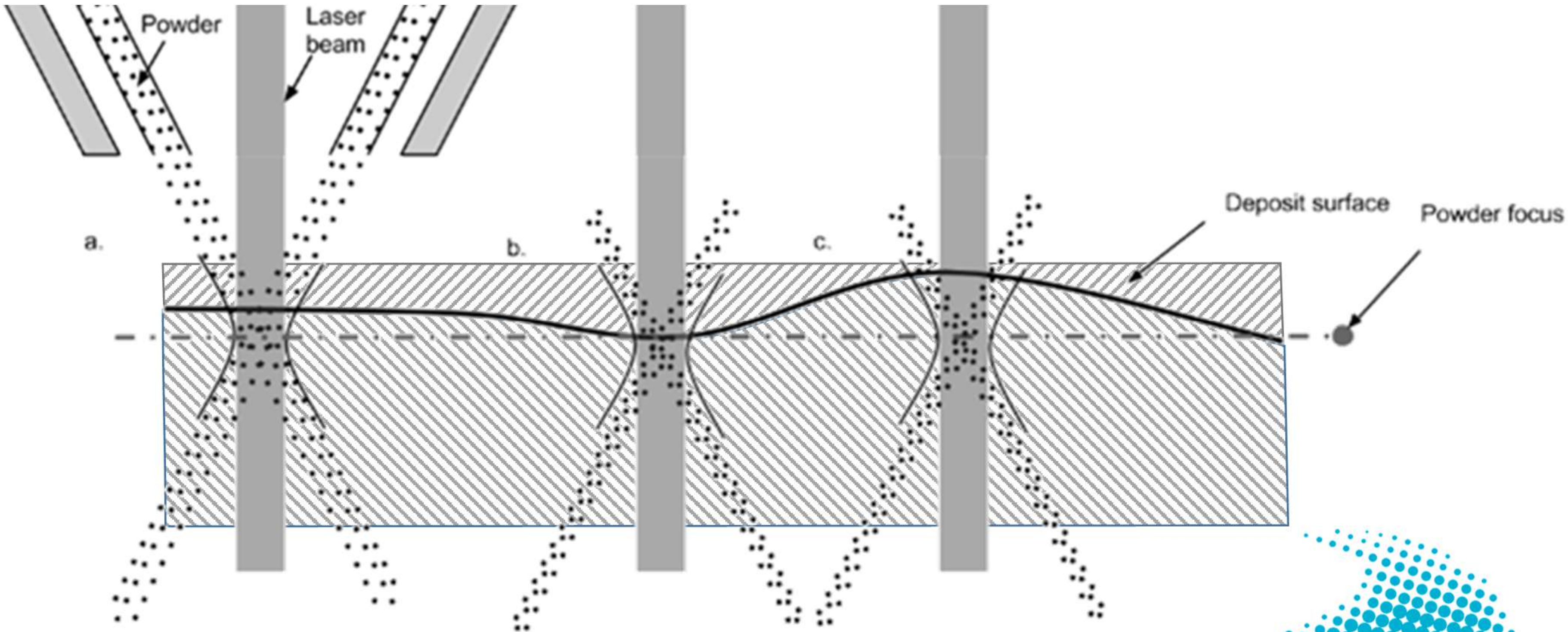
Dimensional characteristics







Surface finish – Effect of powderfocus



Zhu, G., D. Li, et al. (2012). "The influence of laser and powder defocusing characteristics on the surface quality in laser direct metal deposition." Optics & Laser Technology **44**(2): 349-356.

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Conclusions

- The most influential process parameters
  - Width of deposit
    - Laser power
    - Scanning speed
  - Height of deposit
    - Powder feeding rate
    - Scanning speed

  - Negative powder standoff (to a degree) = Straighter top surface (better surface finish)

Main process parameters in present study

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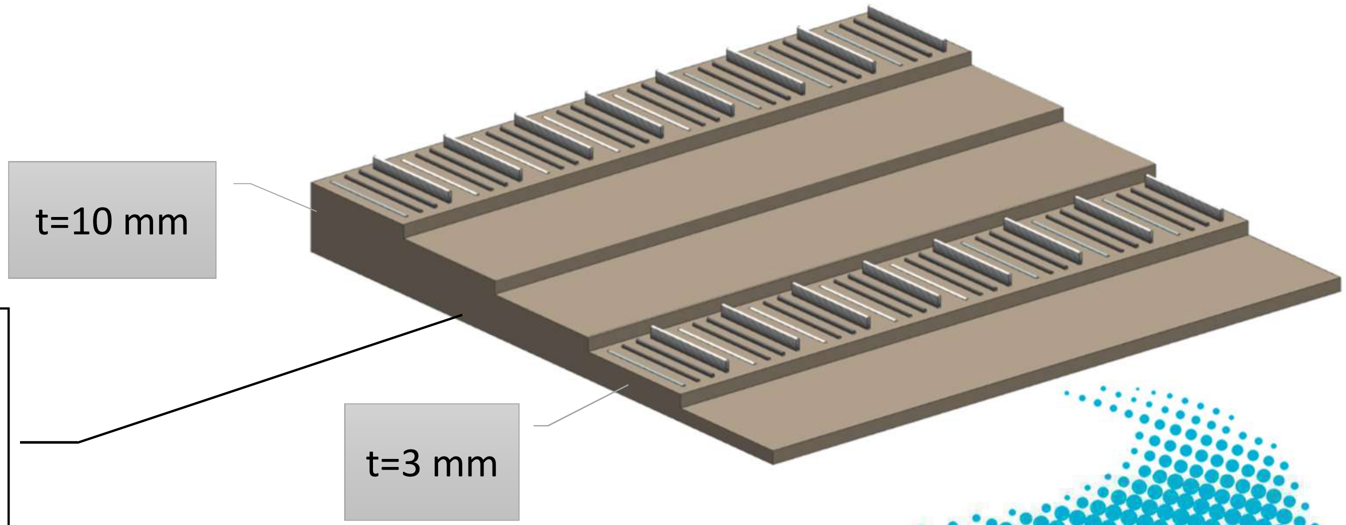
Present work

Two level full factorial design of experiment

Laser power	400 to 1000 W
Scanning speed	10 to 25 mm/s
Powder feeding rate	2 to 10 g/min
Powder standoff	5 to 10 mm

- 16 parameter sets
  - 3 mid-points replicates
  - Each parameter repeated 3 times
- 57 sample runs



- As-cast Alloy 718 substrate
  - Two thicknesses
    - Grain size
    - Segregation
  - In total 114 sample runs

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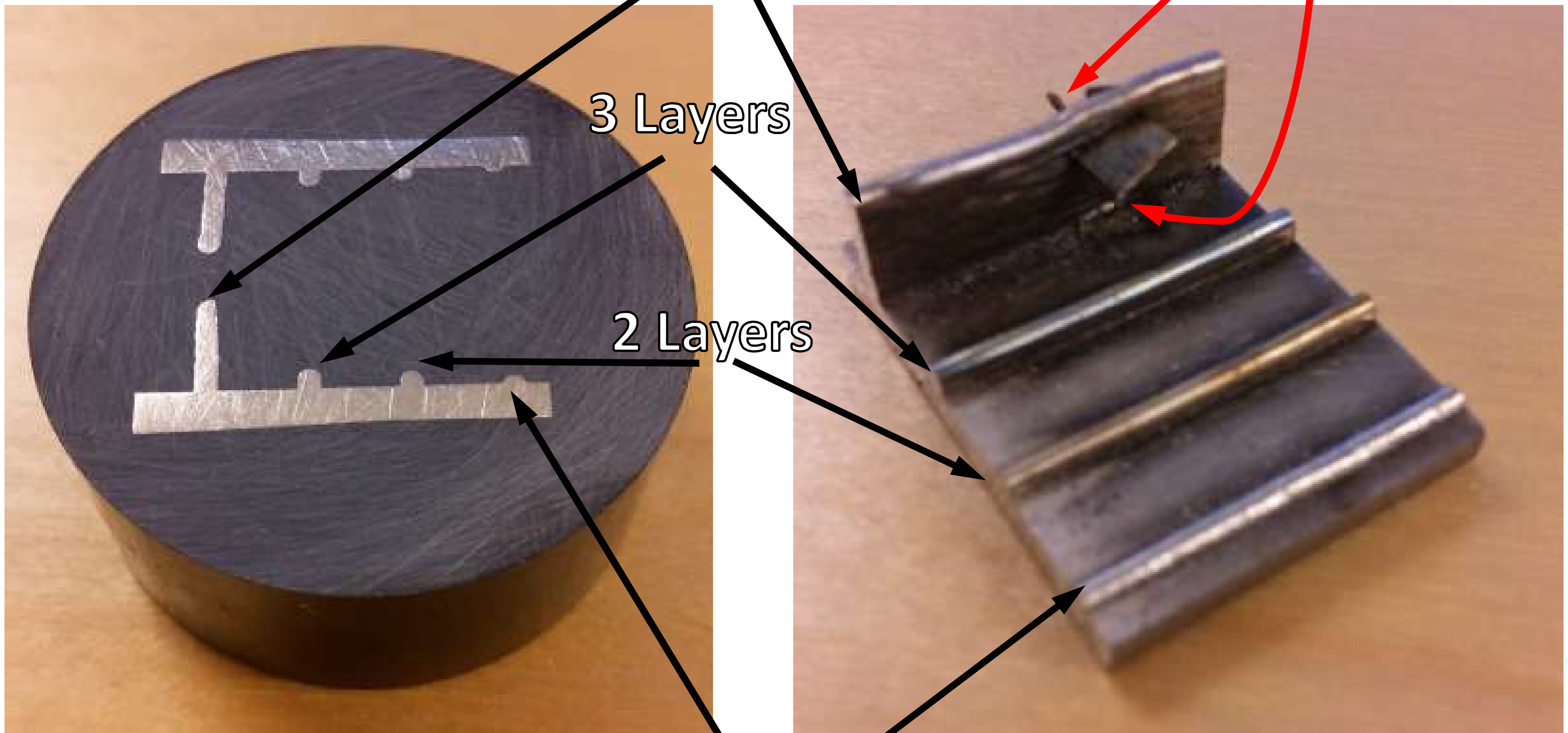
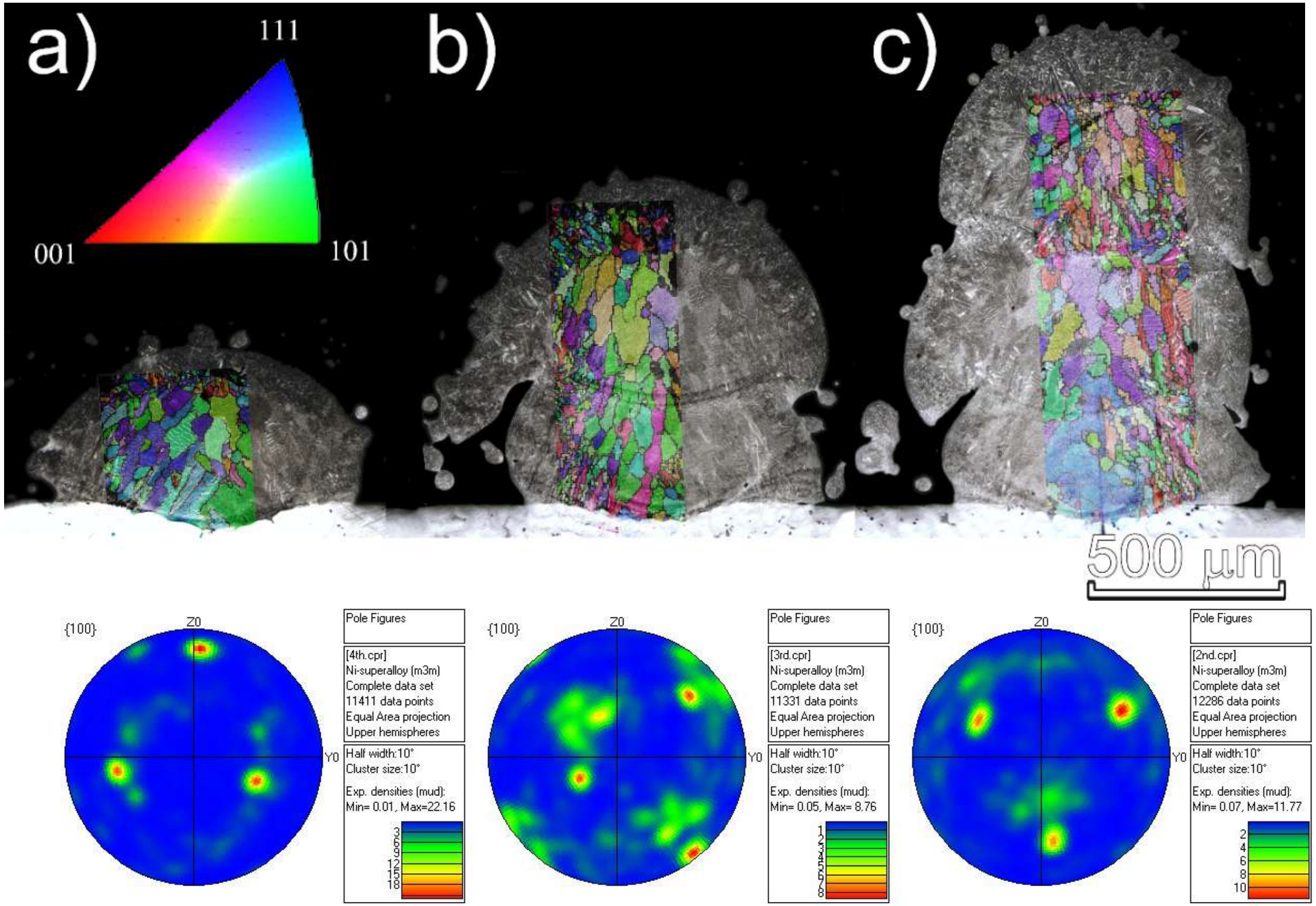
Present work



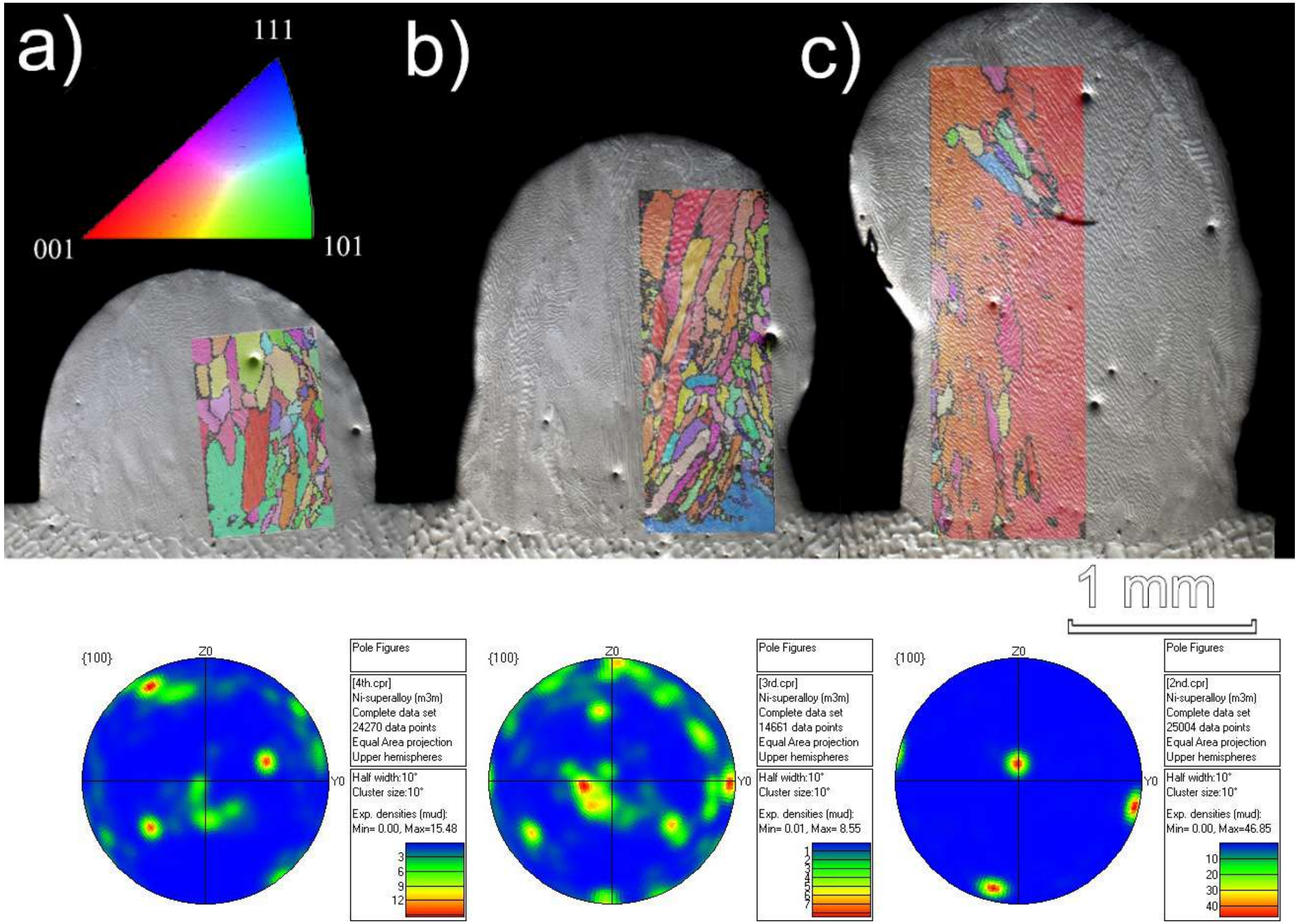
Crystallography – EBSD

- Low heat input (16 J/mm)



Crystallography – EBSD

- High heat input (100 J/mm)



Conclusions

- Vastly different crystallographic structures are attained when changing between a high and a low HI in LMD-p.

- Strong texture using high HI
  - majority of grains growing in the (001) direction along the build-up direction.
  - Crystallographic orientation same for the bottom grains as in the substrate due to epitaxial growth.

- Finer and close to equiaxed grains using low HI
  - Generally weaker texture than in high HI.
  - The low HI leads to a rapid solidification velocity which pushes solutes ahead of the solidification front leading to the nucleation of new grains rather than epitaxial growth.

- However, also in low HI it can be seen that some larger grains are formed in the bottom part of the deposit.

Thank you for your attention!

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