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On the effect of deposition patterns on the residual stress, roughness and microstructure of AISI 316L samples produced by Directed Energy Deposition

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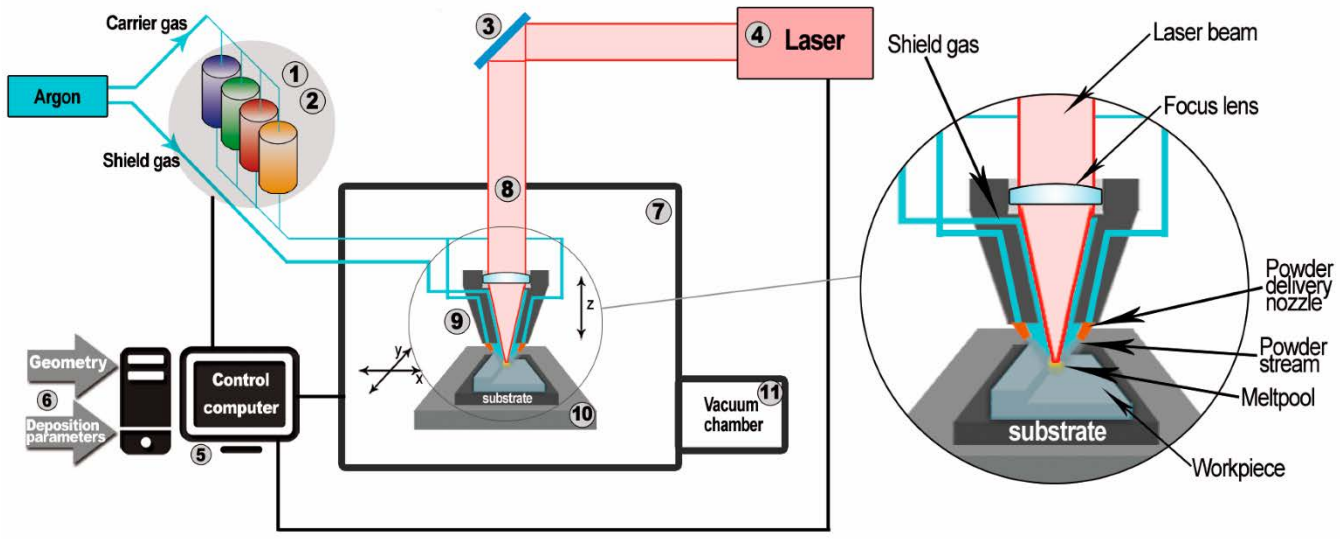
Agenda

- Introduction
- Process overview
- Material and equipment
- Results
- Conclusions and future works

Introduction

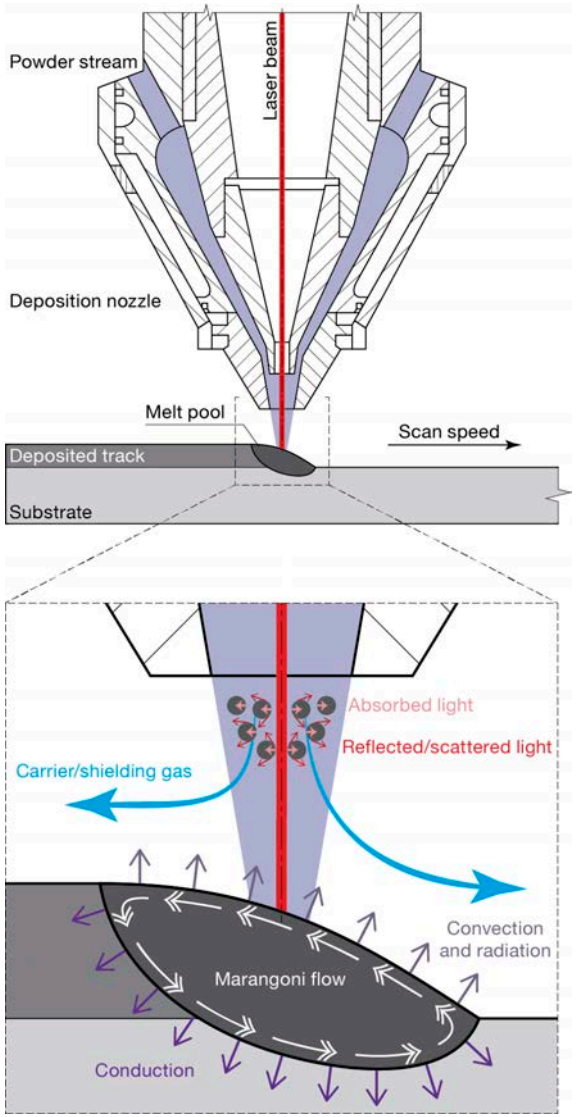
- Metal Additive Manufacturing (AM) processes are recognised as the future of manufacturing industries.
- Producing large metal components is one of the most challenging issues for AM processes.
- Directed Energy Deposition (DED) processes allow this problem to be overcome.
- Laser-Powder Directed Energy Deposition (LP-DED) processes are currently considered premature for industrial applications and one of the main reasons is that the properties of the built parts are not sufficiently optimised.

Process overview



Advantages with respect to the other metal AM processes:

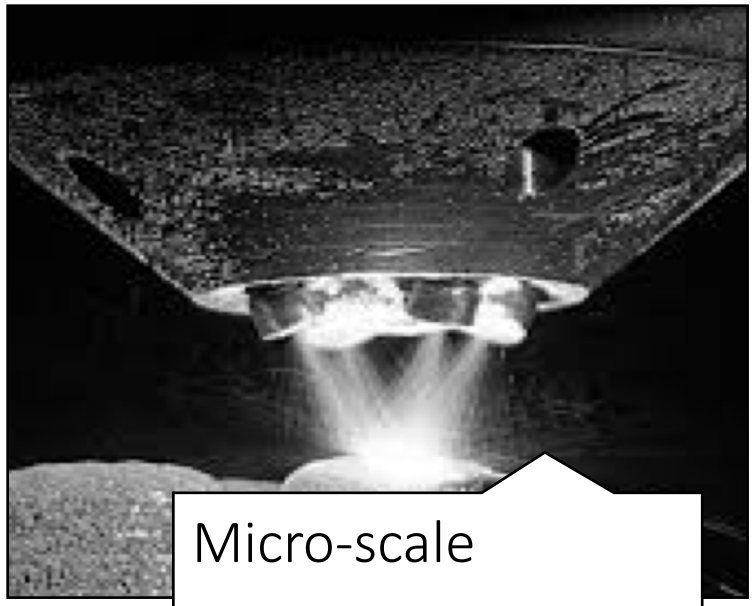
- production of larger components (dimensions bigger than 1 m);
- ability to deposit directly onto existing components;
- production of functionally graded materials by changing materials during the deposition.



Process overview

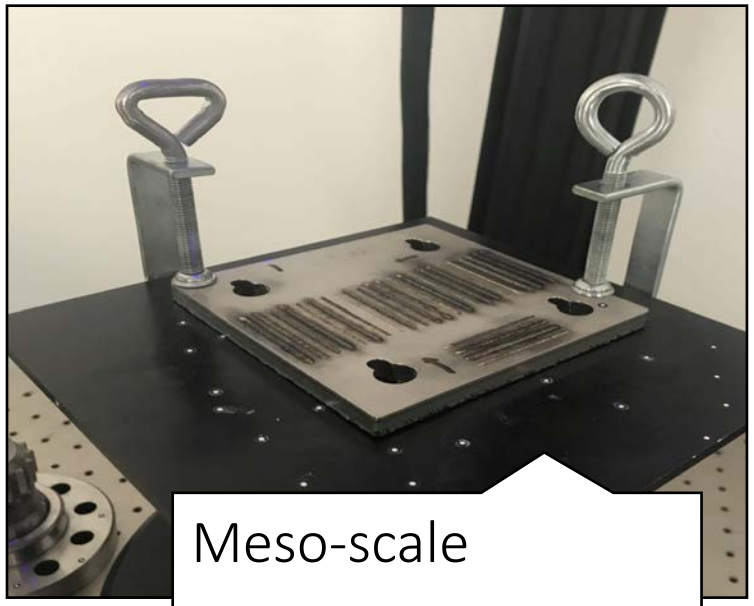
- A laser beam is focused onto the substrate.
- The energy provided forms a melt pool.
- The powder is carried into the melt pool causing the increase in size.
- The process is protected from oxidation by means of a shielding gas (argon).
- When the laser moves away the material solidifies, and a raised track is obtained.

Research overview



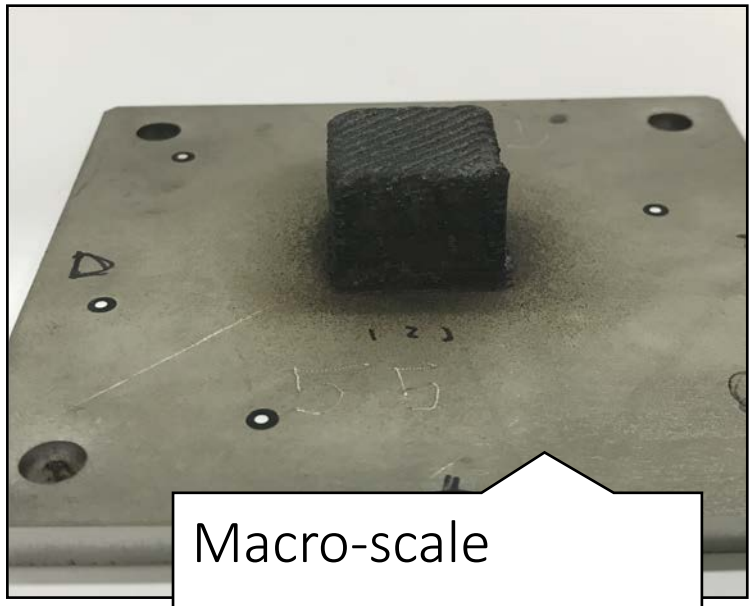
Micro-scale

- Powder stream



Meso-scale

- Single track
  - Track dimensions



Macro-scale

- Component
  - Microstructure
  - Residual stresses
  - Surface roughness

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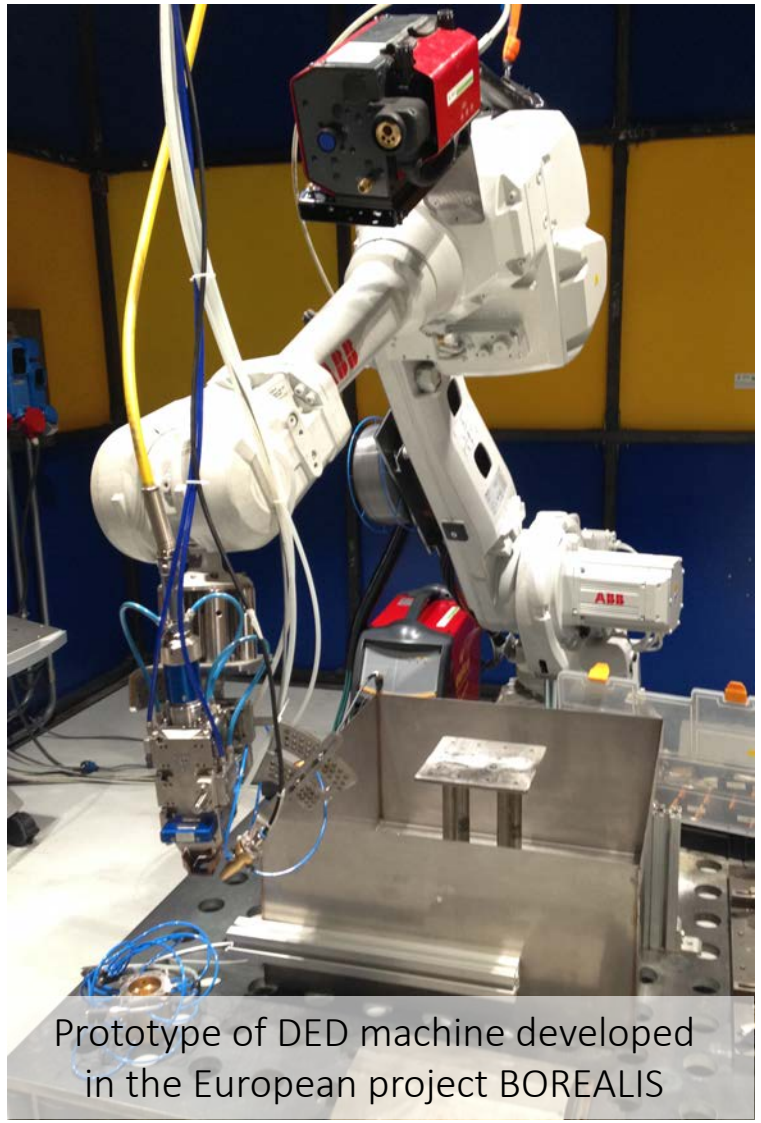


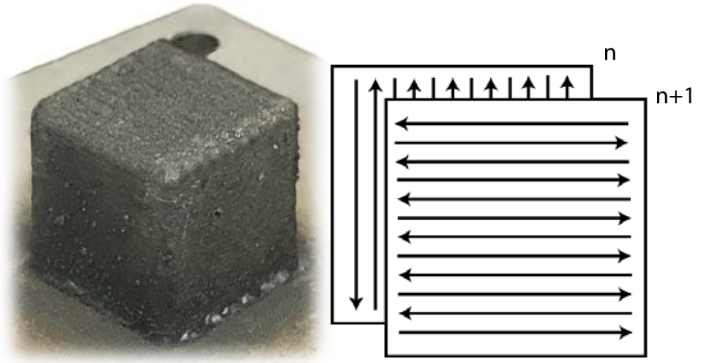
Prototype of DED machine developed in the European project BOREALIS

Material and equipment

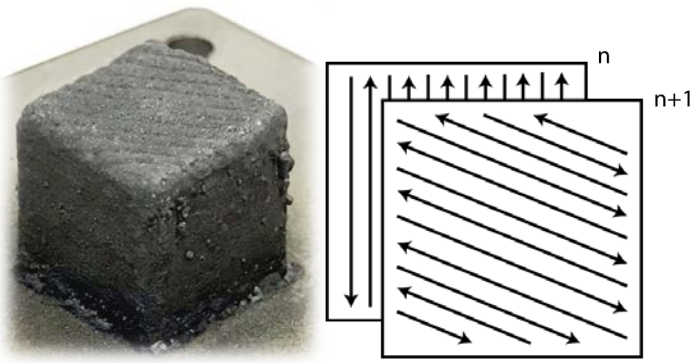
- AISI 316L metal powders were used to produce 20 × 20 × 20 mm^3 cubic samples.
- The considered process parameters were

Laser power, *P*	Laser speed, *v*	Focus, *h*	Powder feeding rate	Carrier gas flow	Overlap in X	Overlap in Z
900 W	15 mm/s	7.5 mm	3.5 rpm	5 l/min	50%	25%

- Using two deposition strategies



0-90°



0-67°

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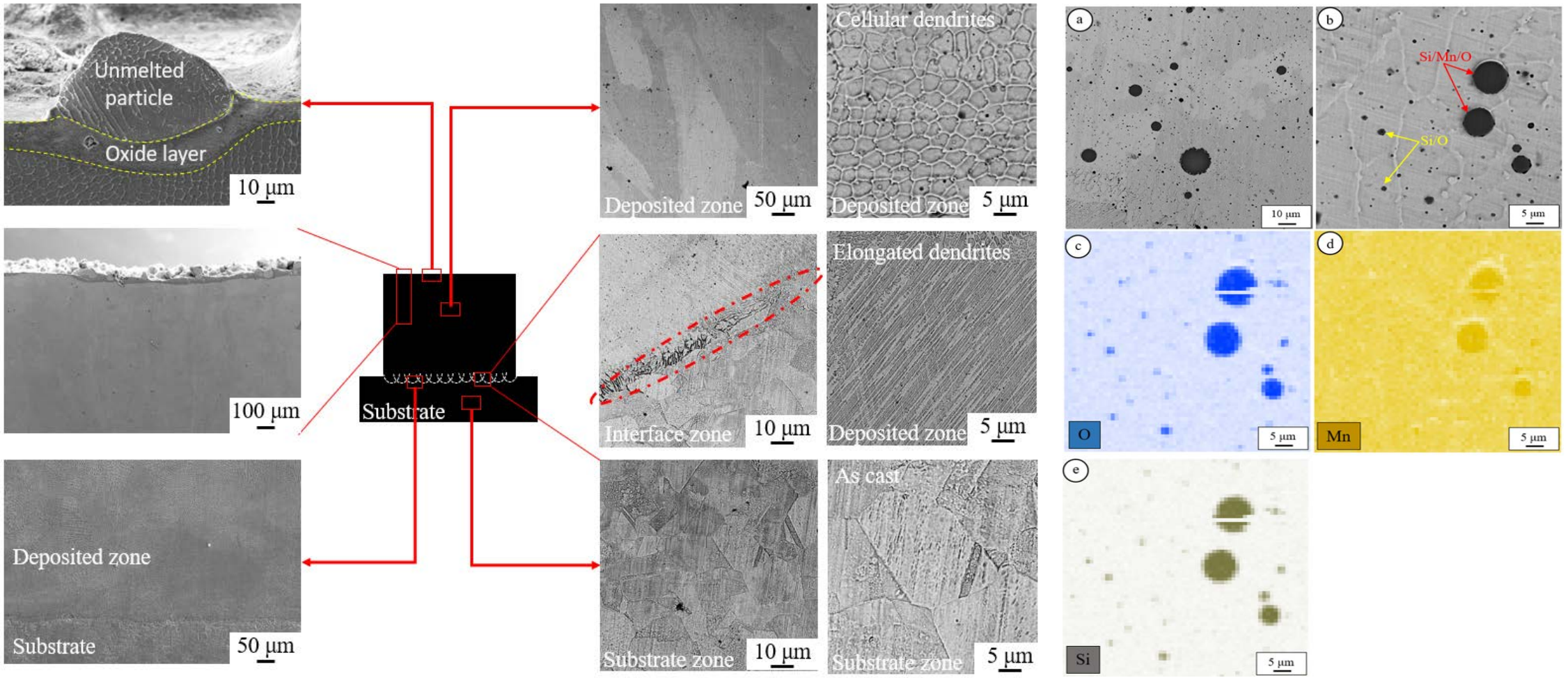
Microstructure – Results



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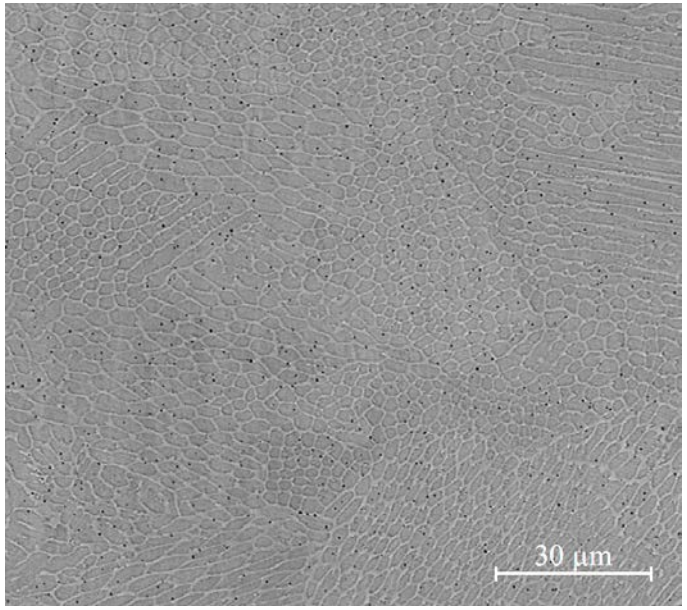
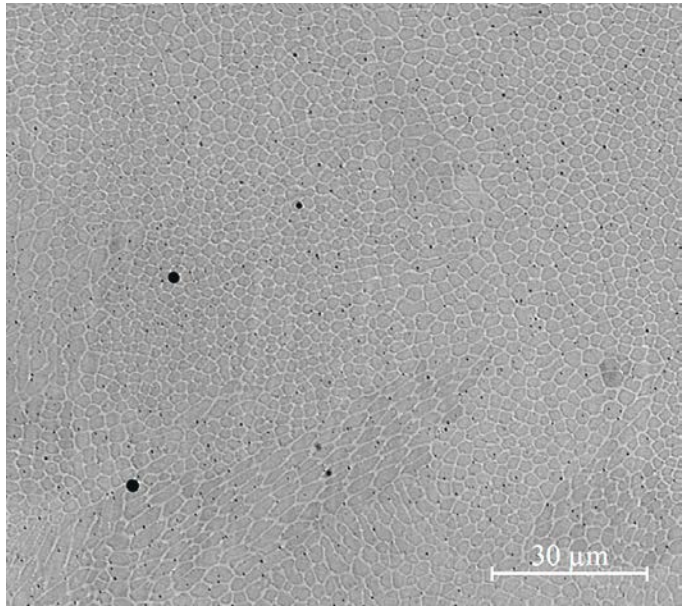
Microstructure – Results

0-90°



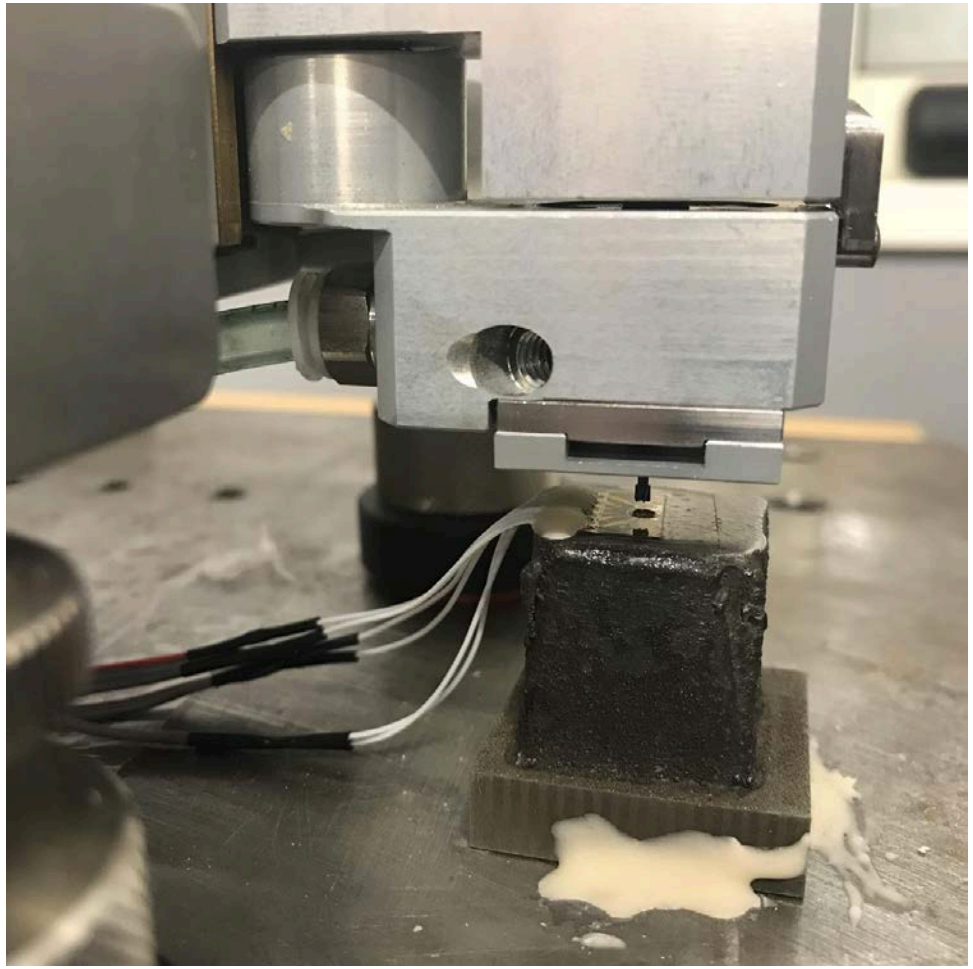
0-67°



- The primary cellular arm spacing (PCAS) of the sample produced using the 0-67° deposition strategy was coarser than the cubes produced using the 0-90° deposition strategy.
- This difference in the PCAS of the cubes produced using different deposition strategy is related to the general cooling rate associated with each rotation.

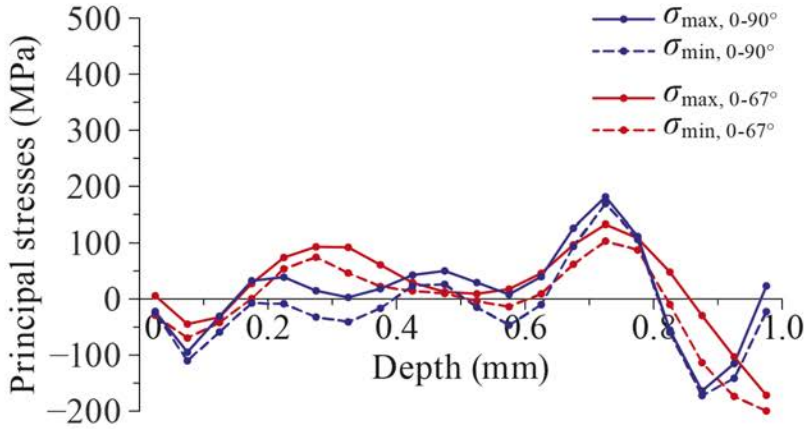
Residual stress measurement

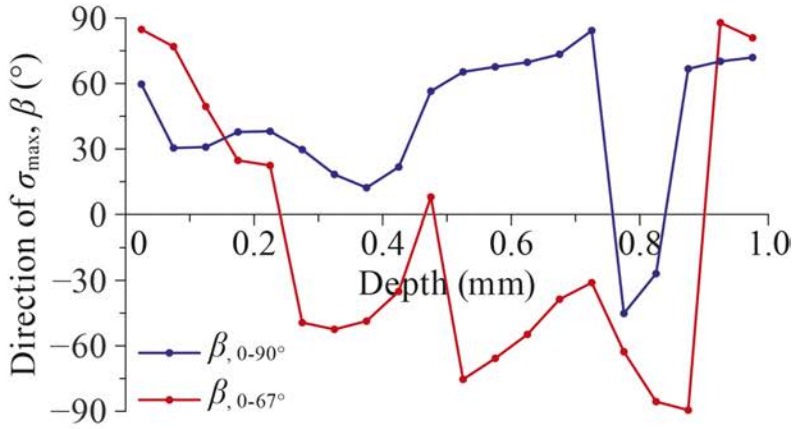
- The residual stress were evaluated using an RESTAN MTS3000 (SINT Technology S.r.l., Italy).
- This system is based on the hole drilling strain gauge method.
- A 1.8 mm diameter drill bit was used to produce a 1.2 mm deep flat-bottom hole, by executing 24 drilling steps to a depth of 50 µm.
- The strains released by the tested material were acquired for each drilling step. A K-RY61-1,5/120R rosette strain gauge, made by HBM, were utilized.
- The acquired strains were introduced into EVAL (SINT Technology S.r.l., Italy) software to back-calculate the residual stresses in compliance with the ASTM E837-13a standard.



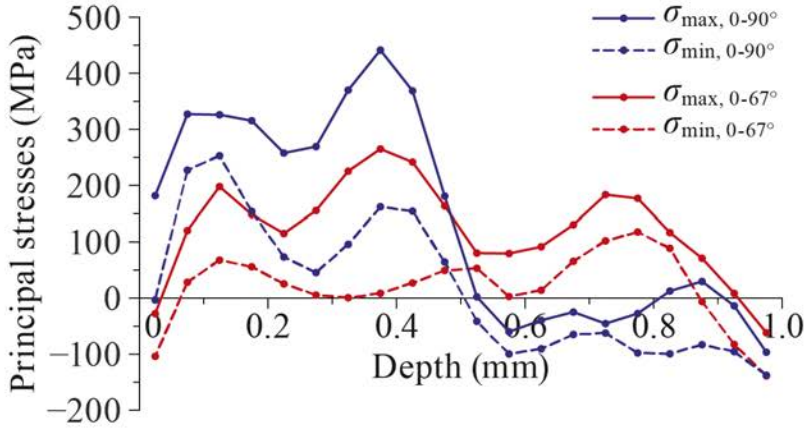
Residual stress measurement – Results

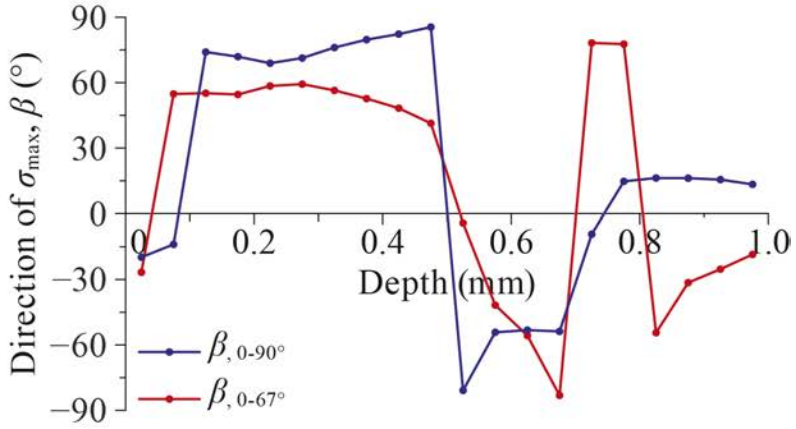
- **On top surfaces** residual stresses are independent from deposition strategy.





- **On lateral surfaces** higher residual stresses are obtained using the 0-90° deposition strategy.





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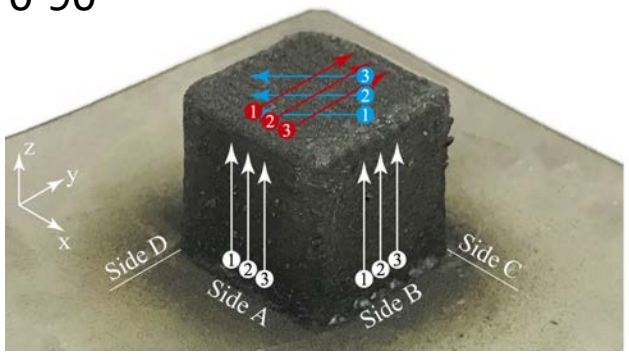
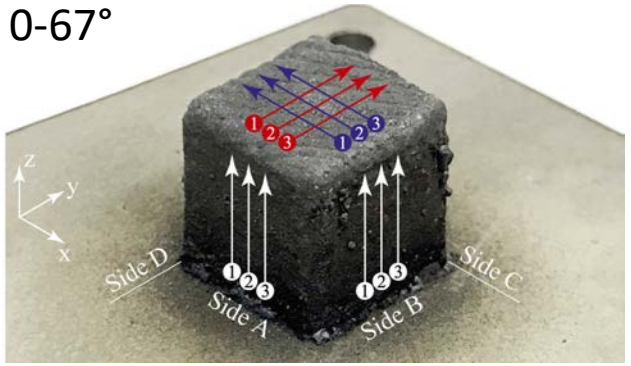
Surface roughness measurement

- The measurements were taken along a profile length of 10 mm using a Gaussian filter and a cut-off of 0.8 mm.
- The measurement were performed on lateral and on top surfaces according to the following strategies:
  - along building direction on lateral surfaces;
  - perpendicular and 45° inclined for 0-90° deposition strategy, along to orthogonal direction for 0-67° deposition strategy.

0-90°



0-67°



RTP80 portable stylus-type surface-roughness tester (SM Metrology Systems S.r.l, Italy).

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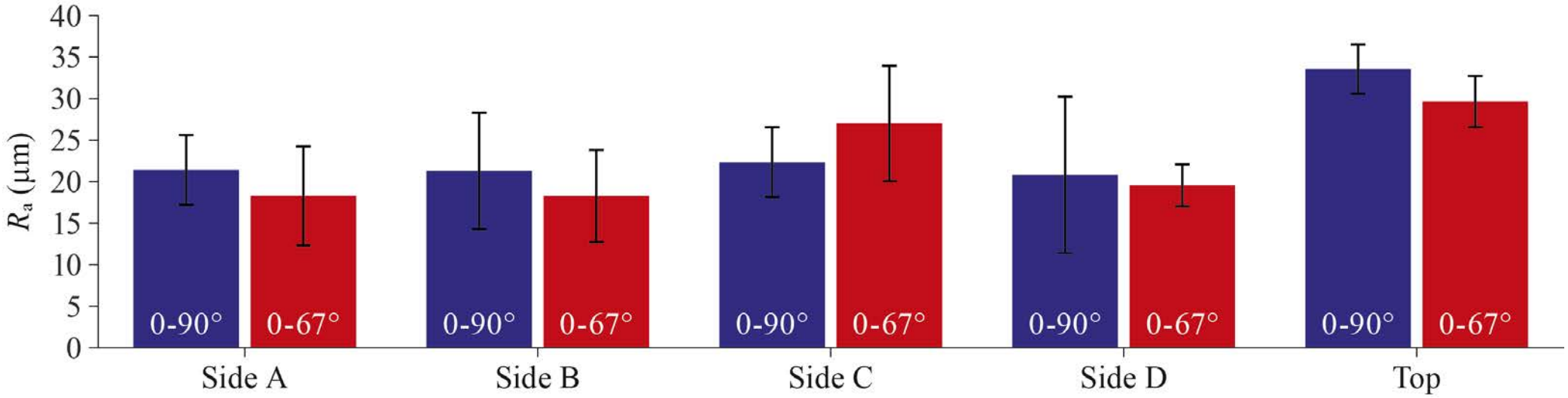
Surface roughness measurement – Results



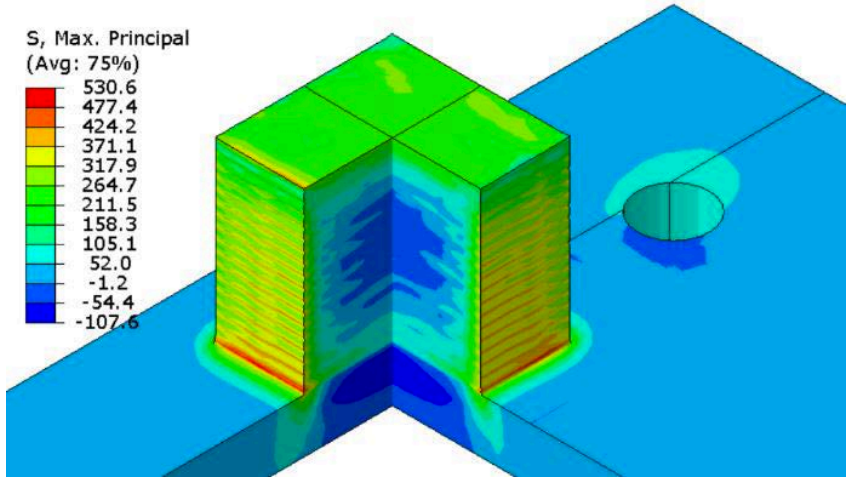
- Deposition strategy does not influence significantly the surface roughness.
- The surface roughness on lateral surfaces is slightly lower respect to surface roughness on top surface.

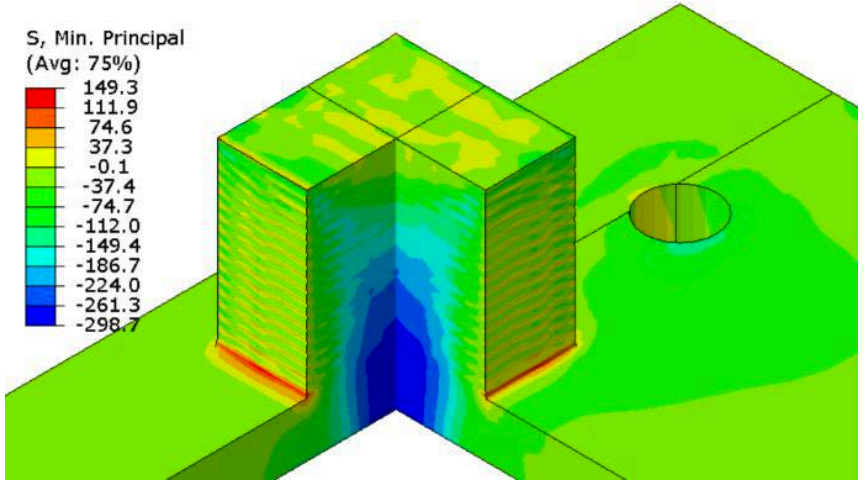
Conclusions

- In this work, the effect of the adopted deposition strategy on the surface roughness, residual stress and microstructure of cubes produced by means of LP-DED has been investigated.
- The main results are:
  - the surface roughness on the top surfaces was higher than that on the lateral surfaces. However the surface roughness was not influenced by the deposition strategy;
  - the residual stresses on the top surfaces were similar for both deposition strategies, although higher stress values were observed on the lateral surfaces of the cubes produced using the 0-90° deposition strategy;
  - a coarse primary cellular arm spacing (PCAS) was observed when the 0-67° deposition strategy was used.

Future works

- Investigate the process feasibility.
- Evaluate the effect of process parameters.
- Development of a numerical model that allows predict the characteristics of the sample.





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Thank you for your kind attention!

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