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DIPARTIMENTO DI MECCANICA
Department of Mechanical Engineering

Le sfide sui materiali per l'Additive Manufacturing, non solo ricerca ma anche opportunità per nuove applicazioni

Material challenges for metal Additive Manufacturing, not only research but also opportunities for new applications

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DIPARTIMENTO DI ECCELLENZA
MIUR 2018-2022

Outline

Alloys for Additive Manufacturing

- ✓ advantages of the rapid solidification
- ✓ … but also disadvantages

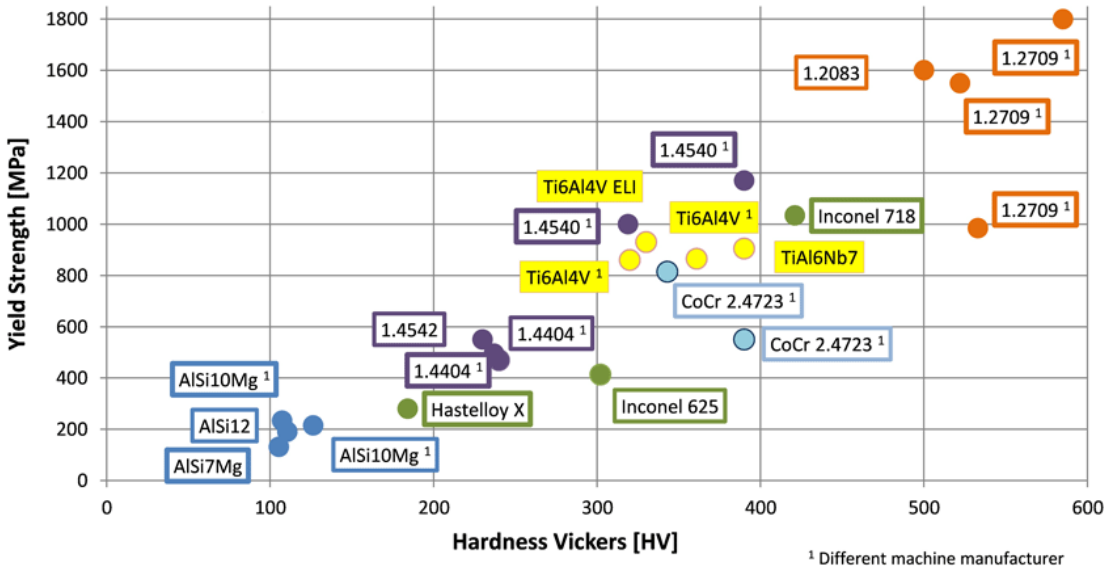
The flexibility of processing conditions

- ✓ opportunities offered by 3D lattices on several size scales

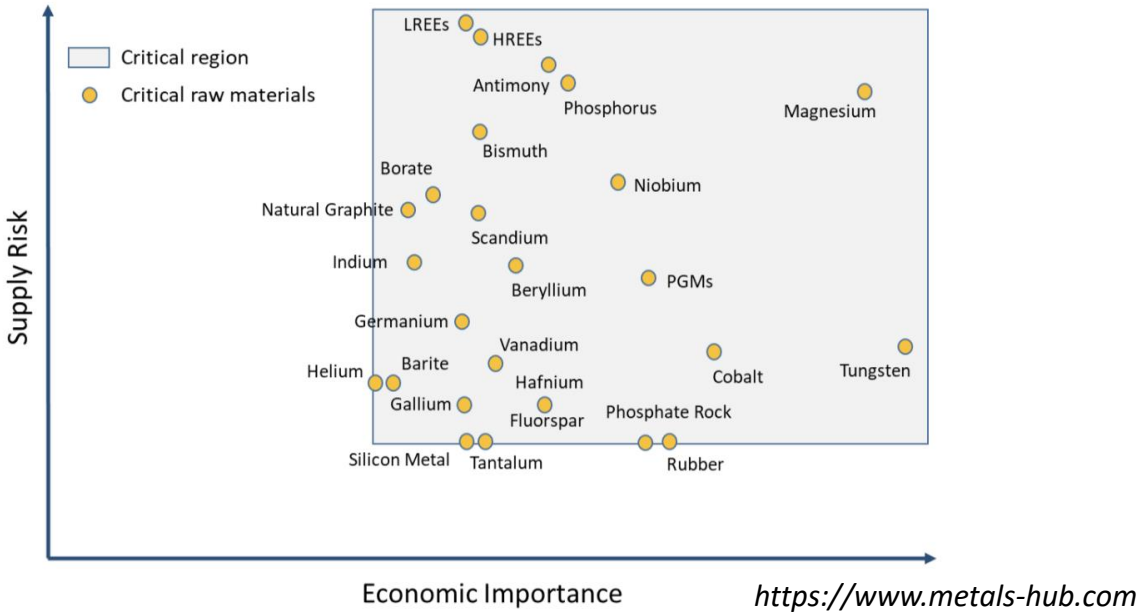
The portfolio of common alloys for AM

The most popular alloys currently available for L-PBF are selected among the traditional materials that can readily be welded and cast

- ✓ These alloys have been designed and optimized decades ago, for other manufacturing routes
- ✓ The patents for new alloys dedicated to AM are exponentially growing in recent years
- ✓ CRM list would also suggest the use of alternative alloys using less critical and cheaper elements



https://www.epma.com



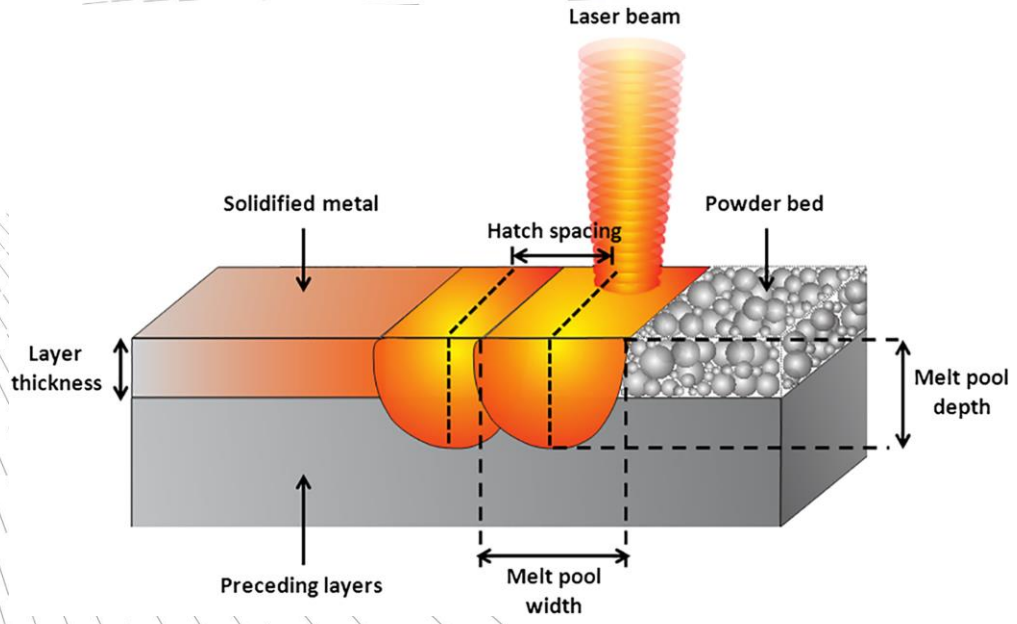
https://www.metals-hub.com

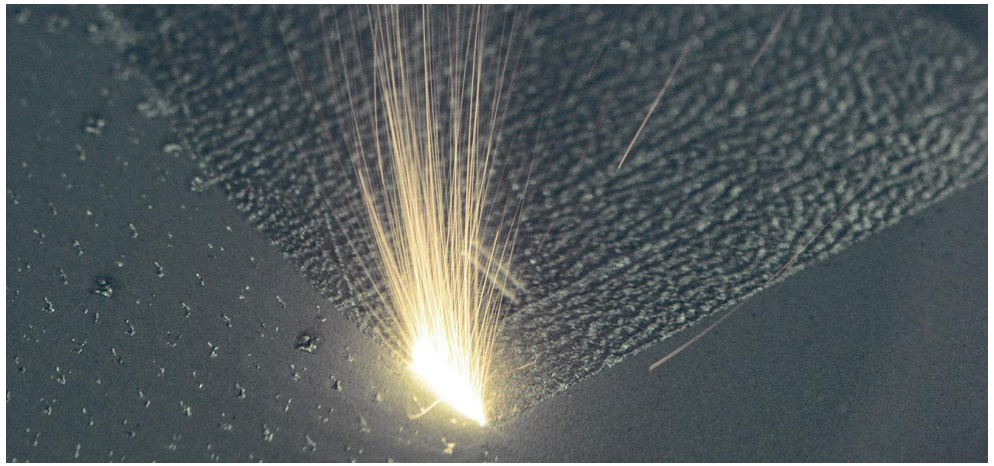
The "environment" of the L-PBF process / powder consolidation

The 3D solid is created by the repeated scanning action of the laser on the powder bed

- ✓ track by track along adjacent paths with partial overlapping
- ✓ layer by layer with partial re-melting of underlying layers

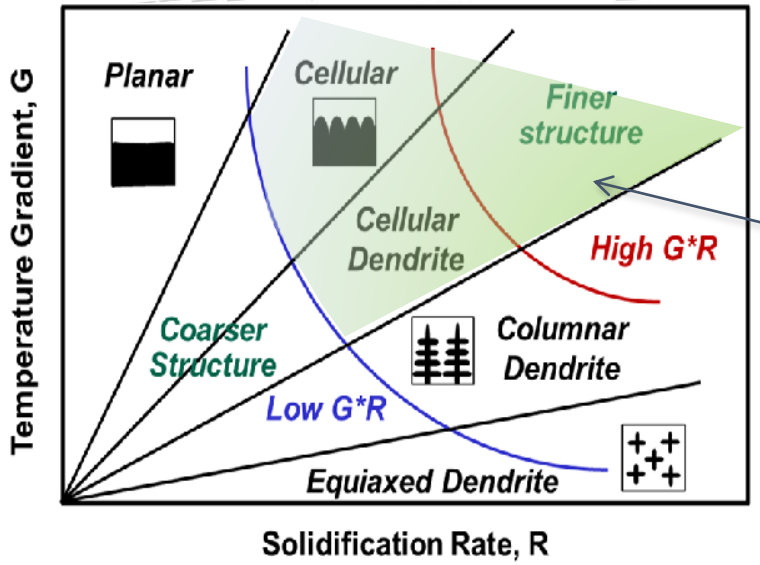
The peculiar processing conditions ask for dedicated alloys to fully exploit the given opportunities

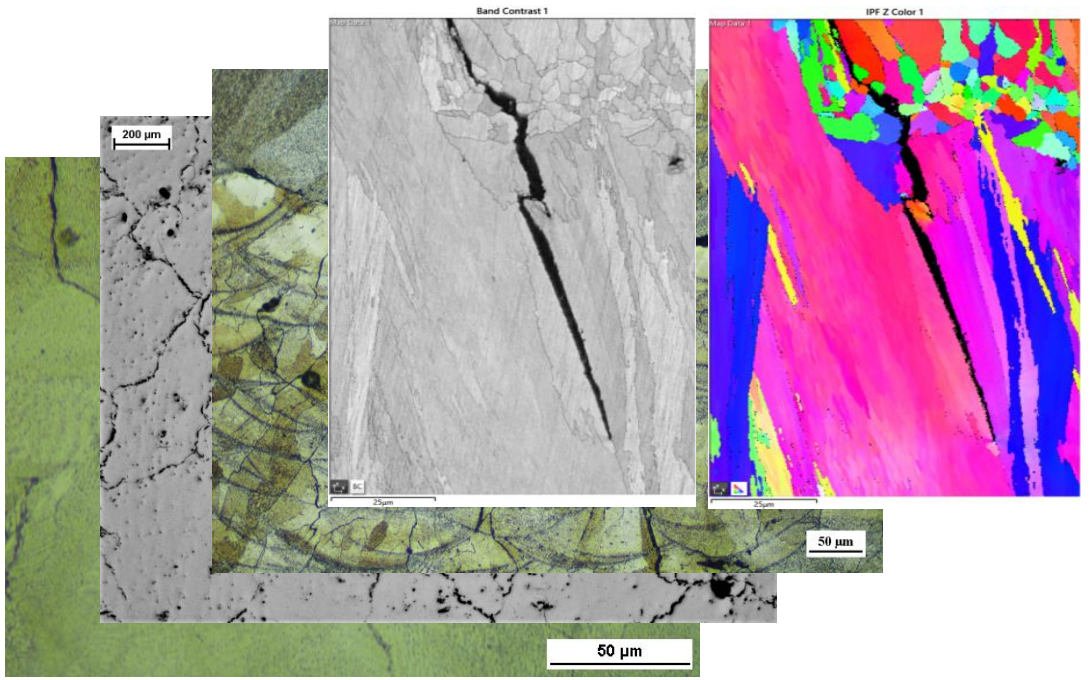




The "environment" of the L-PBF process / mitigation of defects

The fast cooling conditions often create structures that are prone to hot cracking (e.g. high strength Al alloys, precipitation hardened Ni-based superallloys, …)





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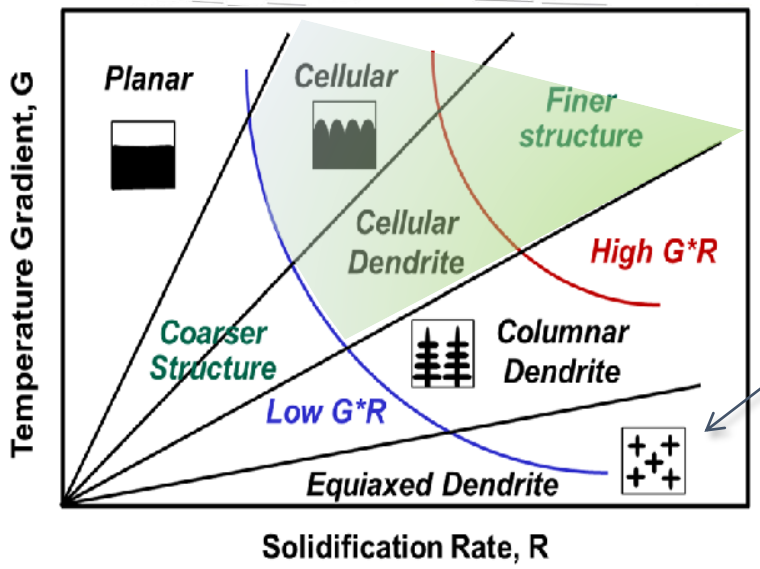
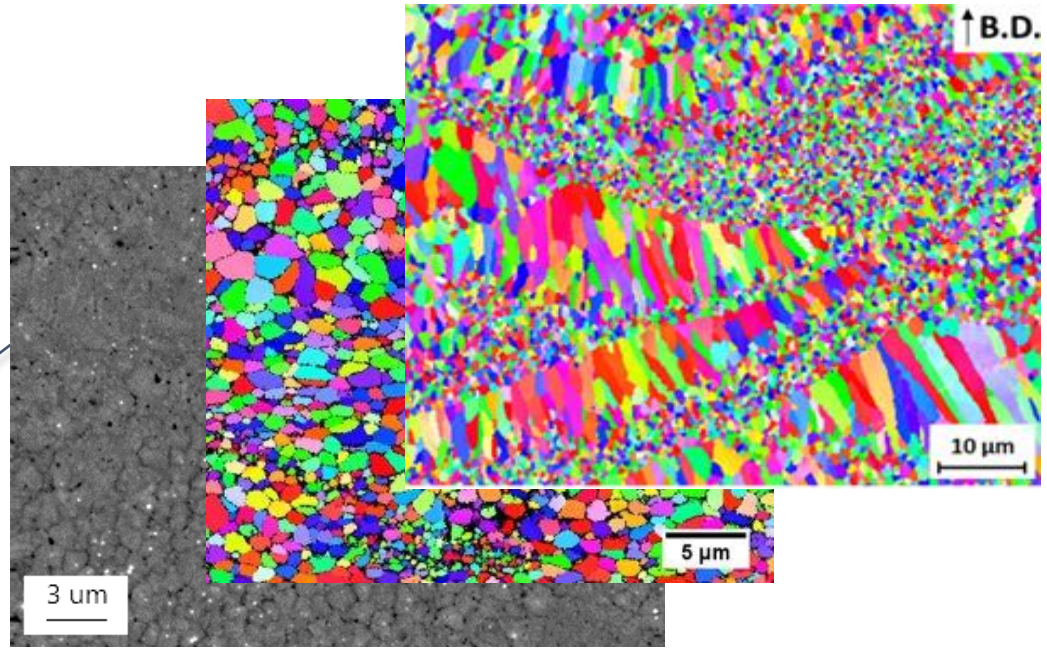
- ✓ New alloys containing nucleants (TiB_2, Zr, Sc, Ti, ….) can promote heterogenous nucleation of grains and formation of finer microstructures, less sensitive to cracks and suppress the formation of textures
- ✓ Other strategies can also be implemented such as contro of solidification range and parameter tuning (esp. Preheating)

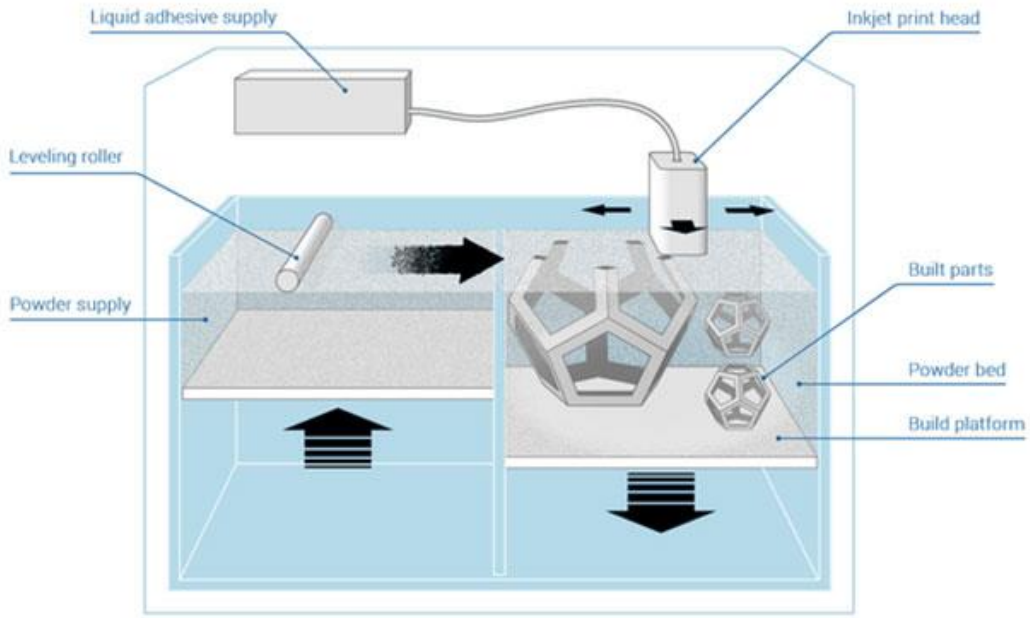


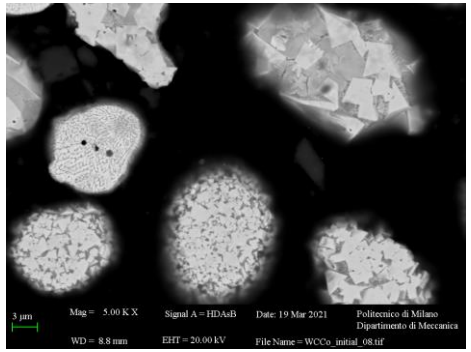


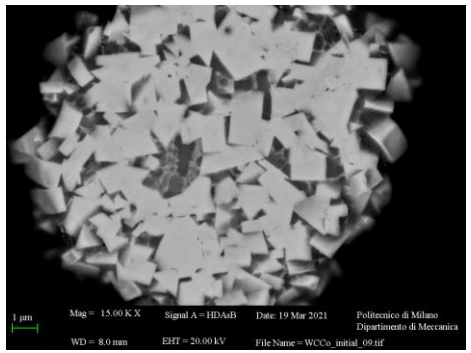
Other alternative AM processes to widen the material range available

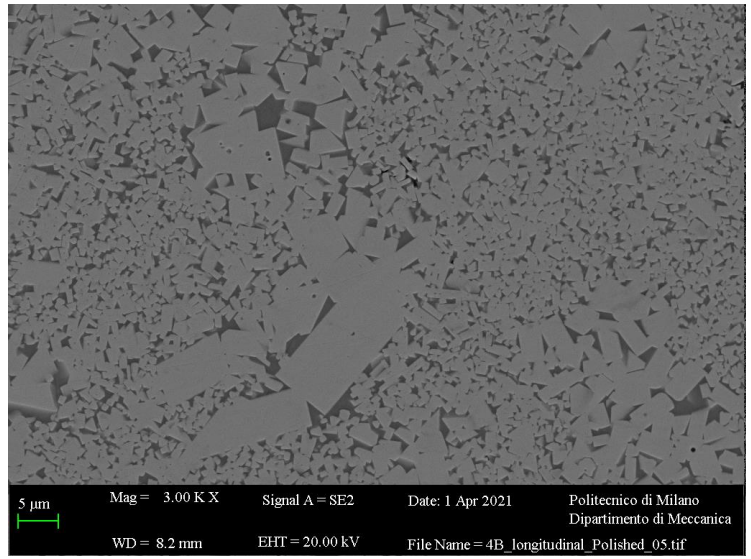
Non-melting powder bed processes such as Binder Jetting make applicable AM for more critical alloys & composites

- ✓ Green parts formed by the selective deposition of a binder (no heat source!)
- ✓ Part consolidation represent important material-related post-process steps: curing / debinding / sintering









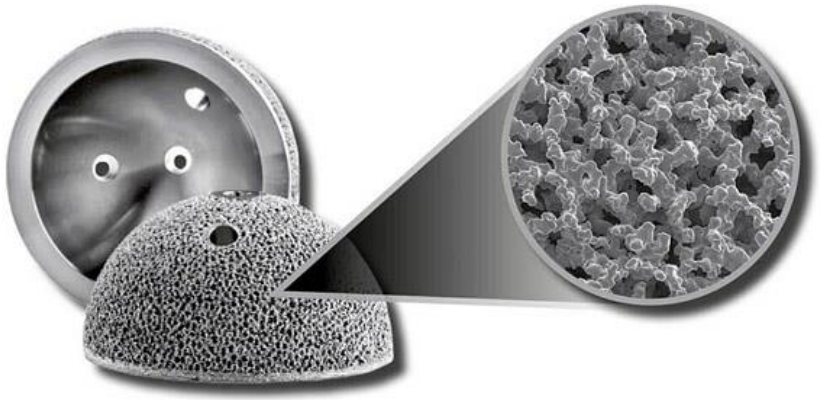
WC-Co hardmetal samples produced by BJ

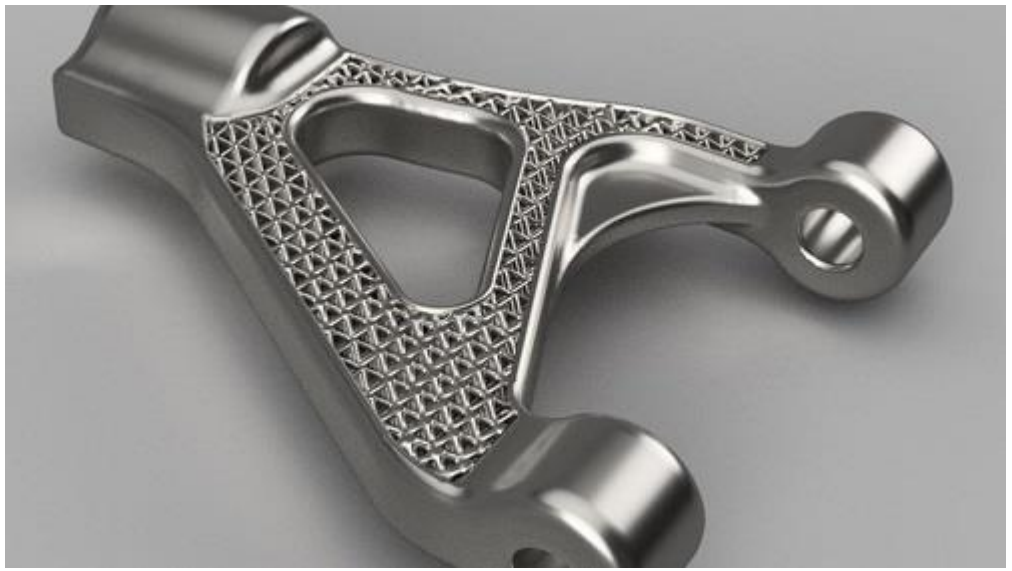
3D lattices as a flexible tool for material design in AM

New properties can be achieved by using 3D lattices and tuning their features

3D structures can be built by AM, targeting important sectors:

- ✓ lightweight design
- ✓ thermal exchange
- ✓ osseointegration
- ✓ vibration damping
- ✓ filtering
- ✓ …





https://www.autodesk.com/

3D lattices as a flexible tool for material design in AM

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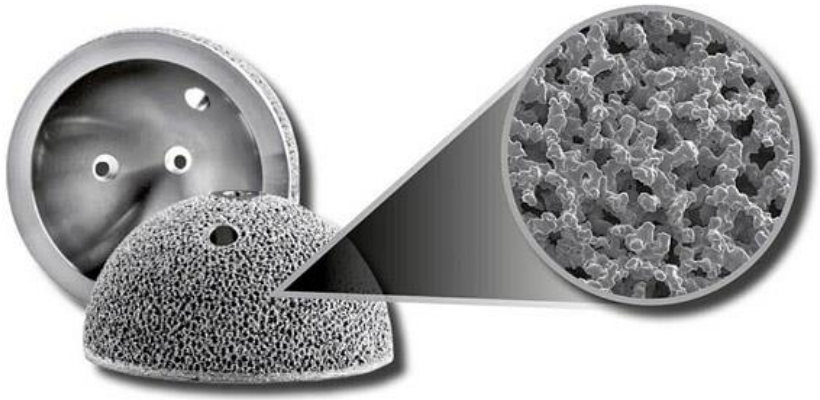
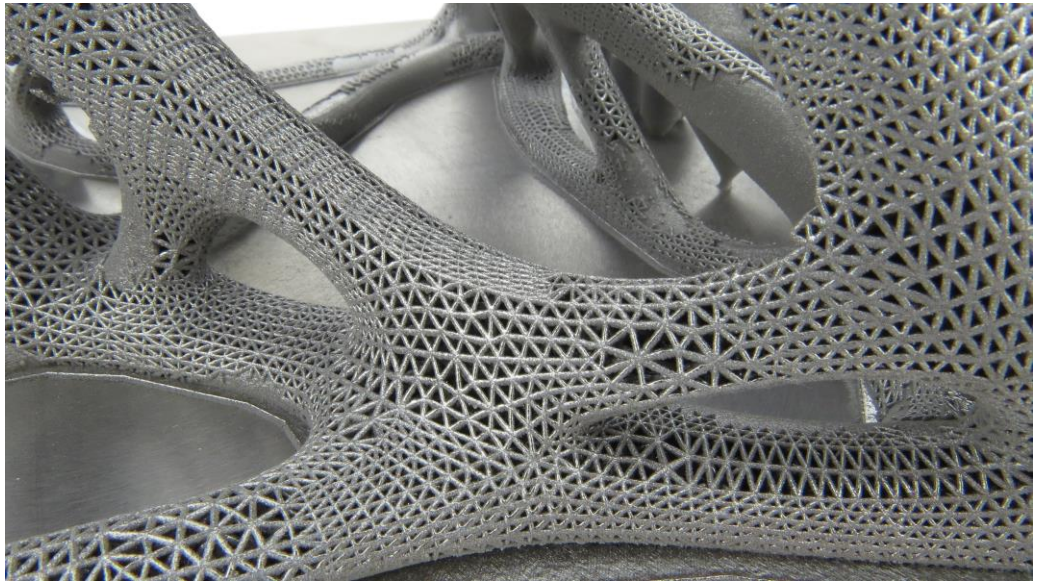




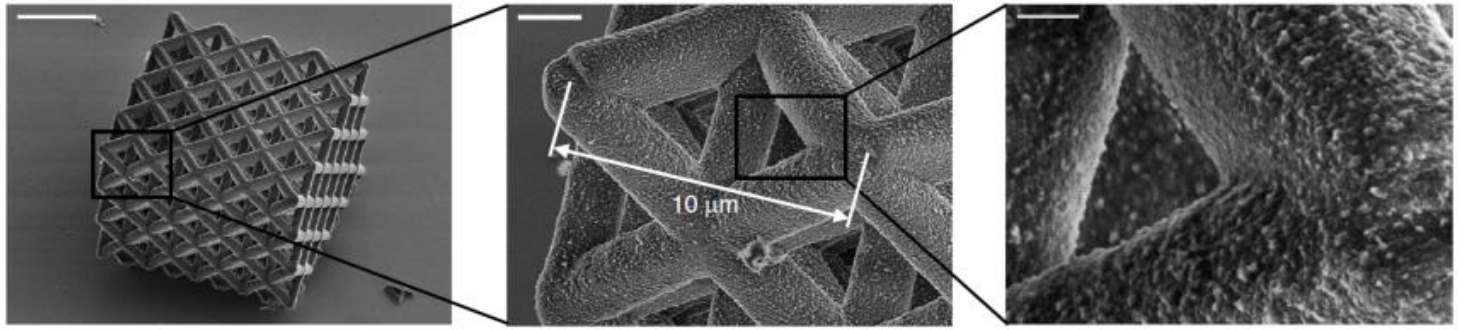
https://resources.renishaw.com/

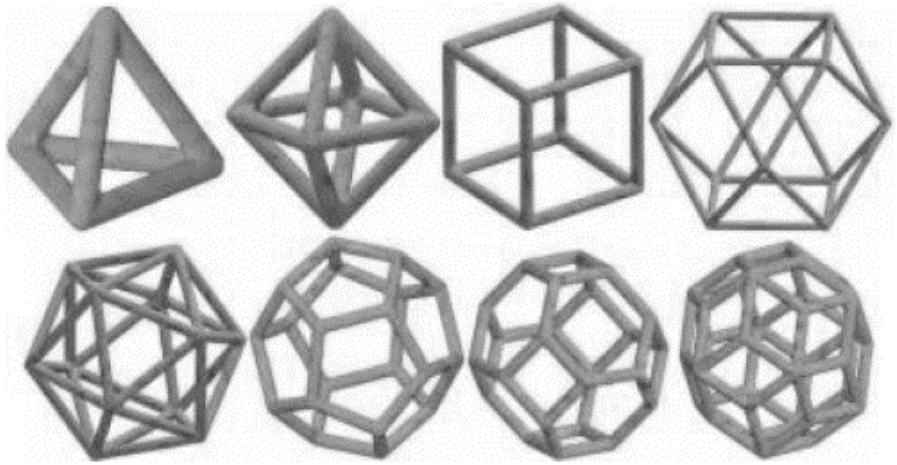
Reducing the cell size of 3D lattices for special applications

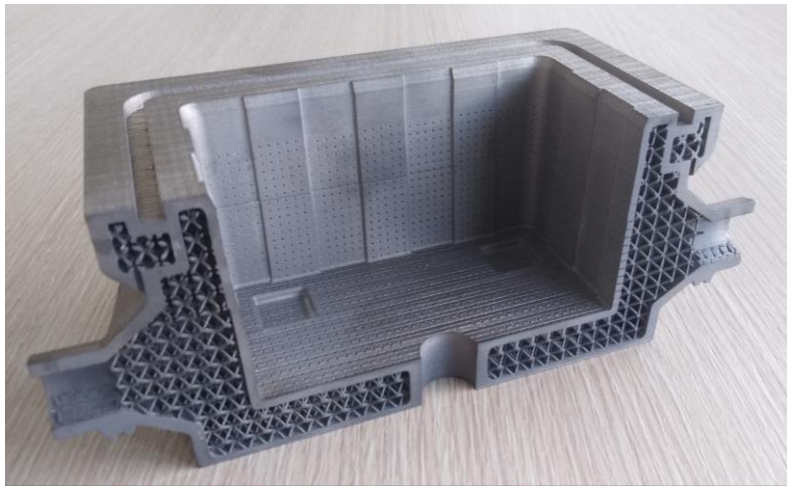
Several variables are available to add degree of freedom for material design

- ✓ Size scale of cells, moving from macro to micro scale
- ✓ Geometry of the unit cell
- ✓ Density gradient
- ✓ Hybrid structures
- ✓ …

A. Vyatskikh et al. Nature Communications 9 (2018) 593







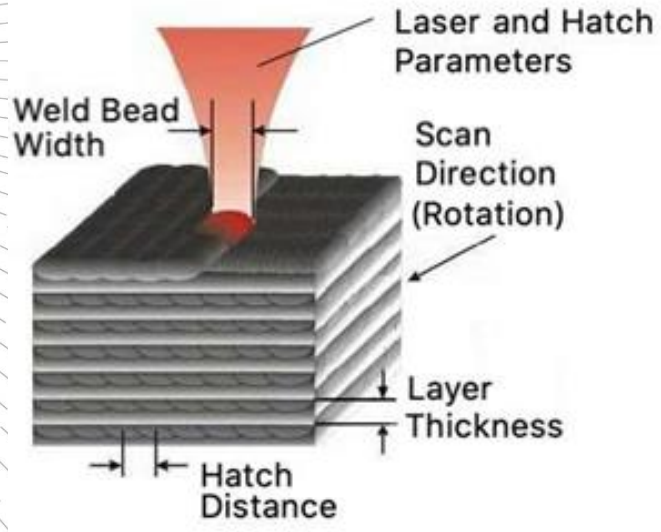
ALESSIOHITECH

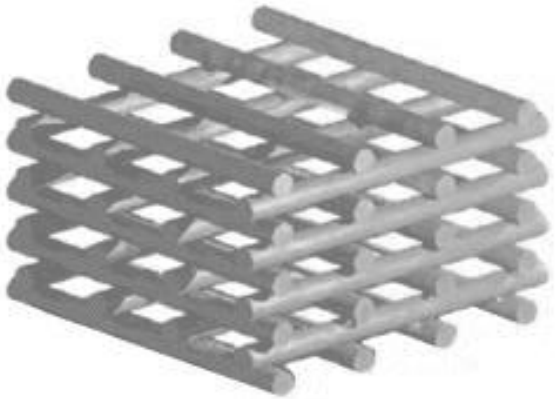
3D micro-lattices produced by tuning the process

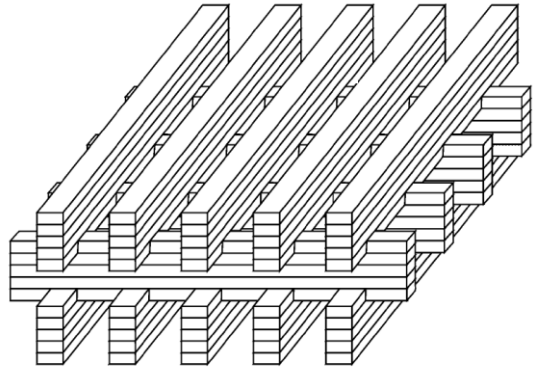
SHAREBOT

As opposed to lattices designed within the CAD model, 3D structures at the small scale can be generated by proper tuning of the process parameters

- ✓ the lattice is only created at the printing stage
- ✓ STL files and printing data are kept very «light»



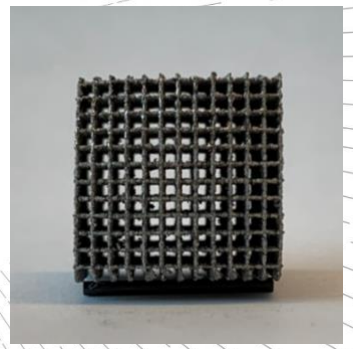


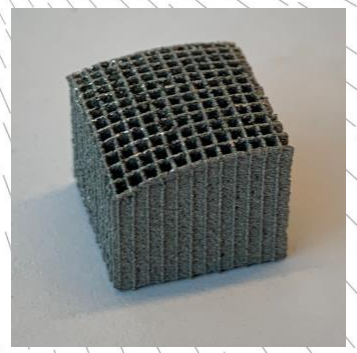


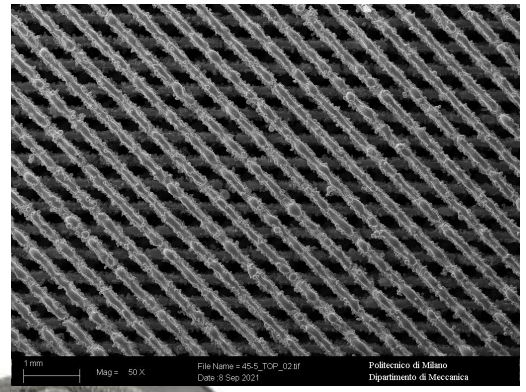
3D micro-lattices produced by tuning the process

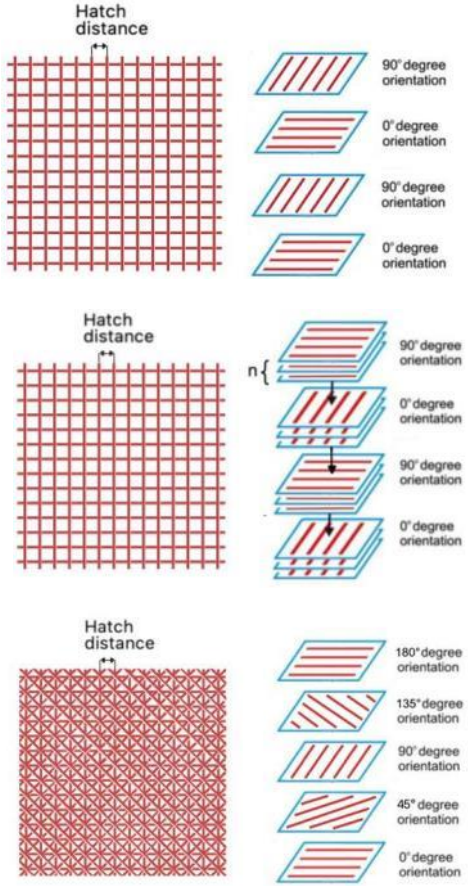
Research on this topic is currently in progress @ PoliMi in cooperation with Sharebot

- ✓ Sample lattices have been created in Ti-6Al-4V alloy and 316L stainless steel
- ✓ Cubes and simple shapes can be created using standard scanning strategies
- ✓ Complex geometries need more flexible tools to define the proper scanning paths





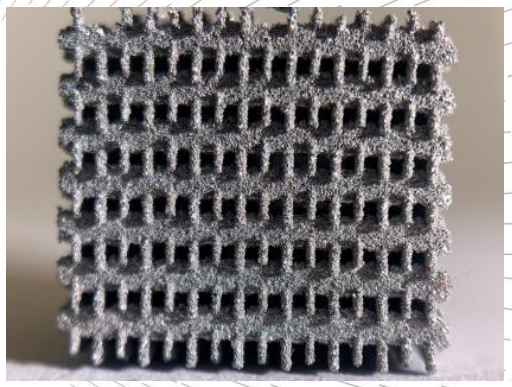


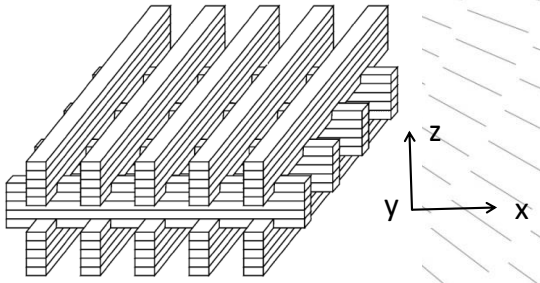


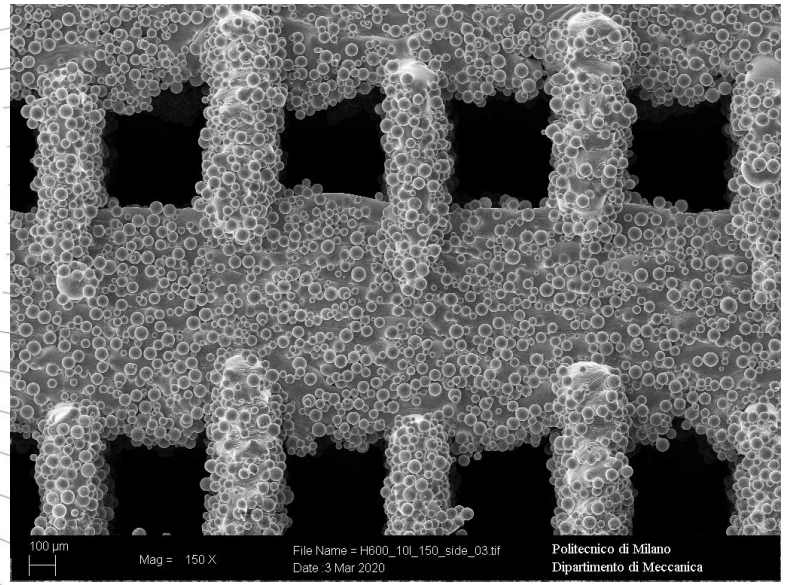
Sample cubes of side 10 mm produced with hatch distance from 400 um to 1200 mm

3D micro-lattices produced by tuning the process

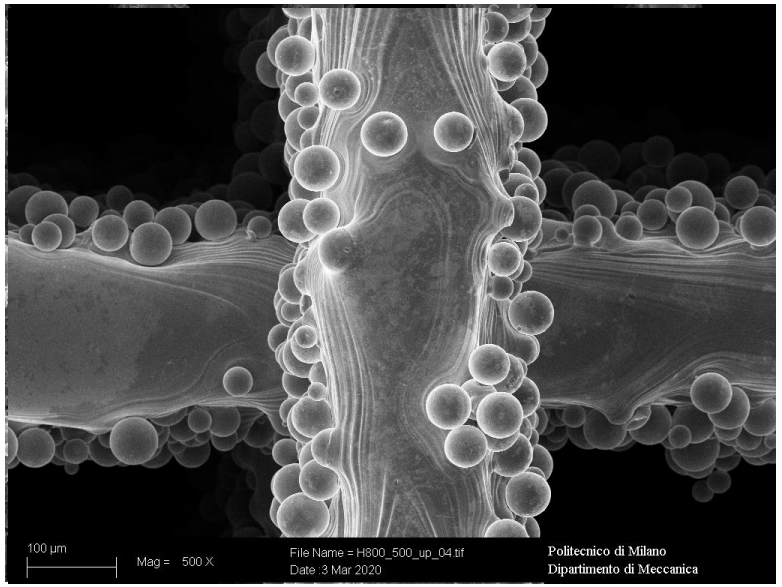
- ✓ Hatch distance 600 um, 90° rotation each «n» layers







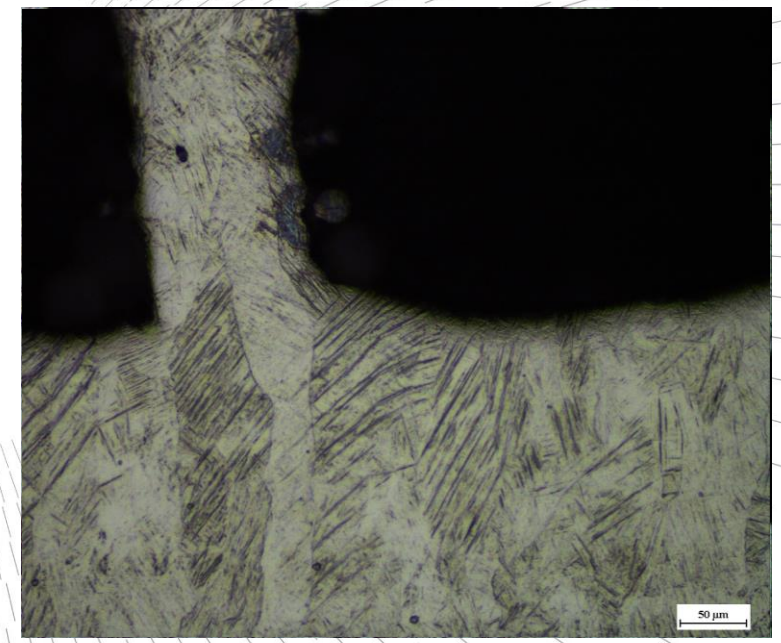
Lateral view

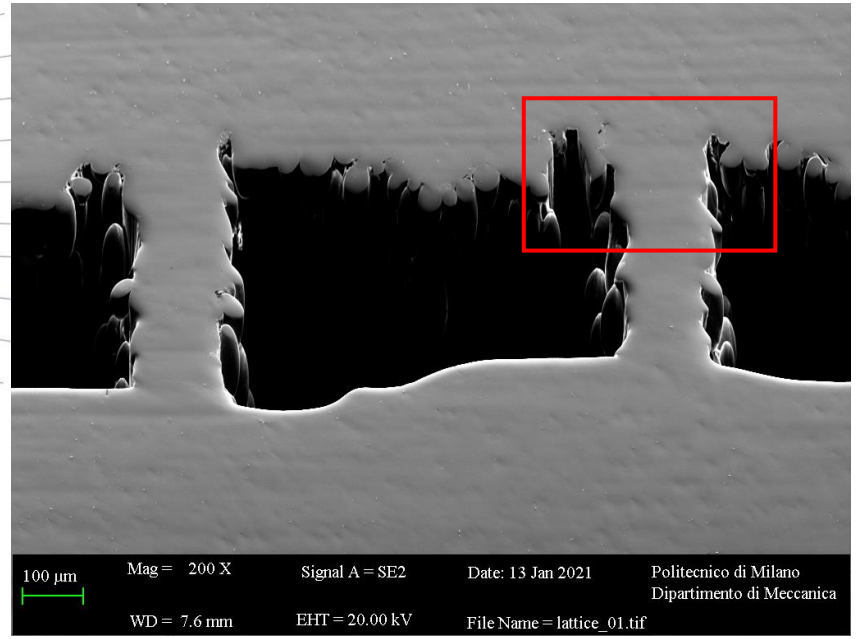


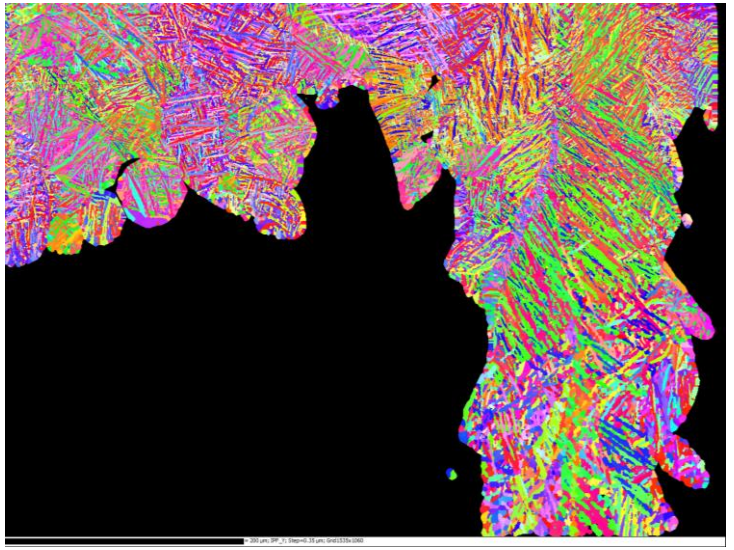
Top view

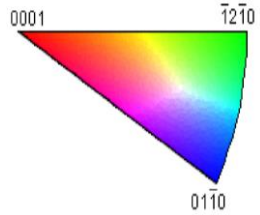
3D micro-lattices produced by tuning the process

Connections among intersecting struts is created by the partial remelting of the underlying volume to guarantee a good welding and a continuous microstructure









Conclusions

The scenario of metallic alloys for AM is subjected to rapid evolution owing to new opportunities and requests for industrial applications

Materials and process development cannot be considered separately, especially for the case of AM

- ✓ New alloys should be designed considering criticalities growing from processing conditions,
- ✓ Specific AM technologies (BJ) offer the opportunity of processing class of materials that are otherwise unprocessable by AM
- ✓ 3D lattices (esp. micro-lattices) are becoming an interesting «material alternative» for lightweight and other new applications

Thanks for your kind attention!

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