Printing Metals and Light Absorbing Ceramics, using the DLP method

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Additive World 'Industrial 3D Printing Conference'

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Eindhoven
22 March, 2016

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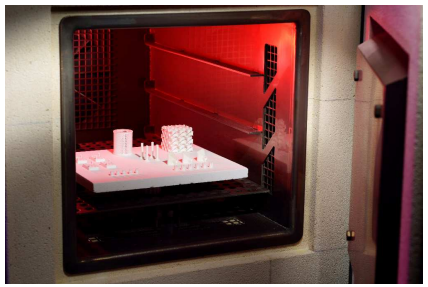
Why DLP AM for metals and light absorbing ceramics

Using the strengths of the Powder Metallurgy (PM) basic process



blending

↓

shaping

↓

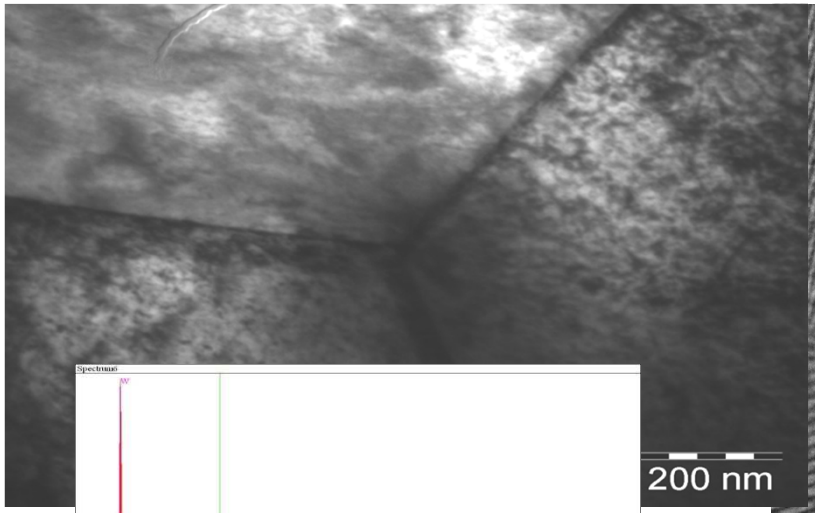
sintering

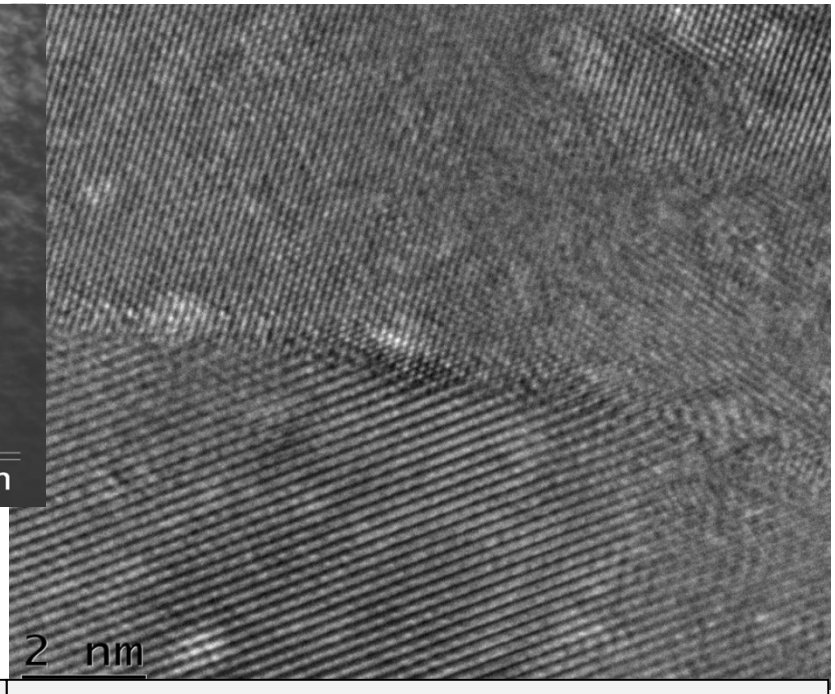
- Particle size, distribution, shape
- Impurities
- Homogeneity
- Stability
- Strength green product
- Sintering dopes
- Sintering ambient, Temp
- Density / porosity

Advantages of PM based DLP technology

- Isotropic properties and microstructure
- Stress free material
- Segregation free
- Ultra high purity materials
- Flexibility by unique alloying/doping

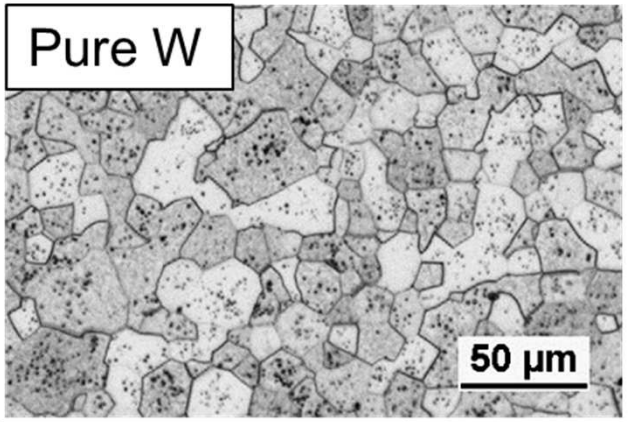
High Resolution TEM of pure W

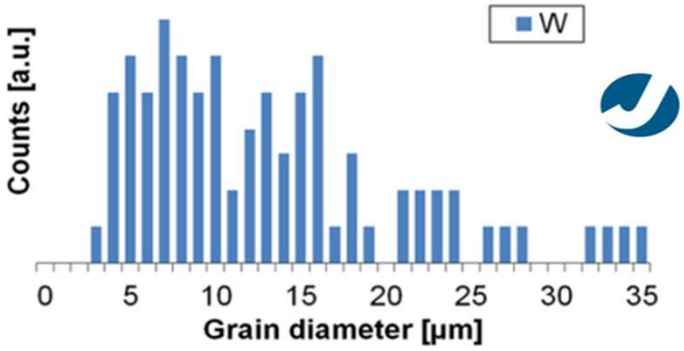


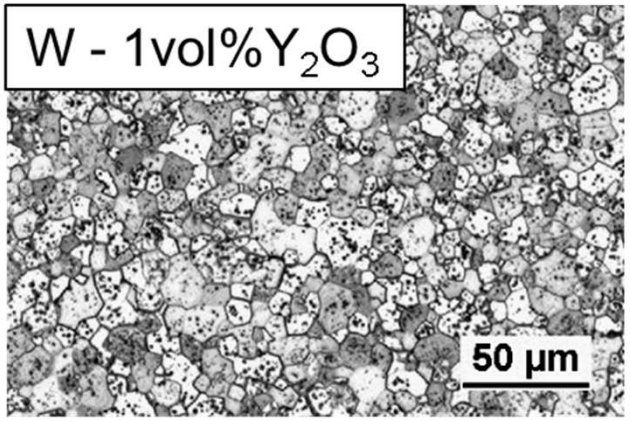


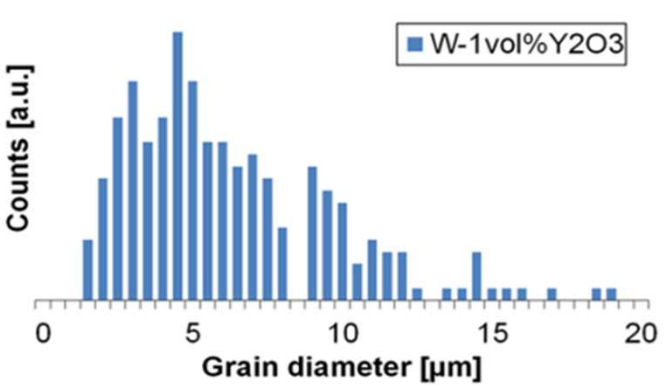
Triple junctions (TJs) and grain boundaries (GBs) analysed by contrast in HRTEM and by X-EDS.	**representative observed atomic structure of a GB in the material. No impurity atoms or amorphous phase are seen on these GBs.**

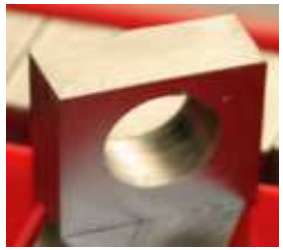
Controlled Microstructure by doping alloying (MIM W by ECN)





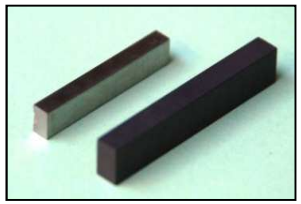


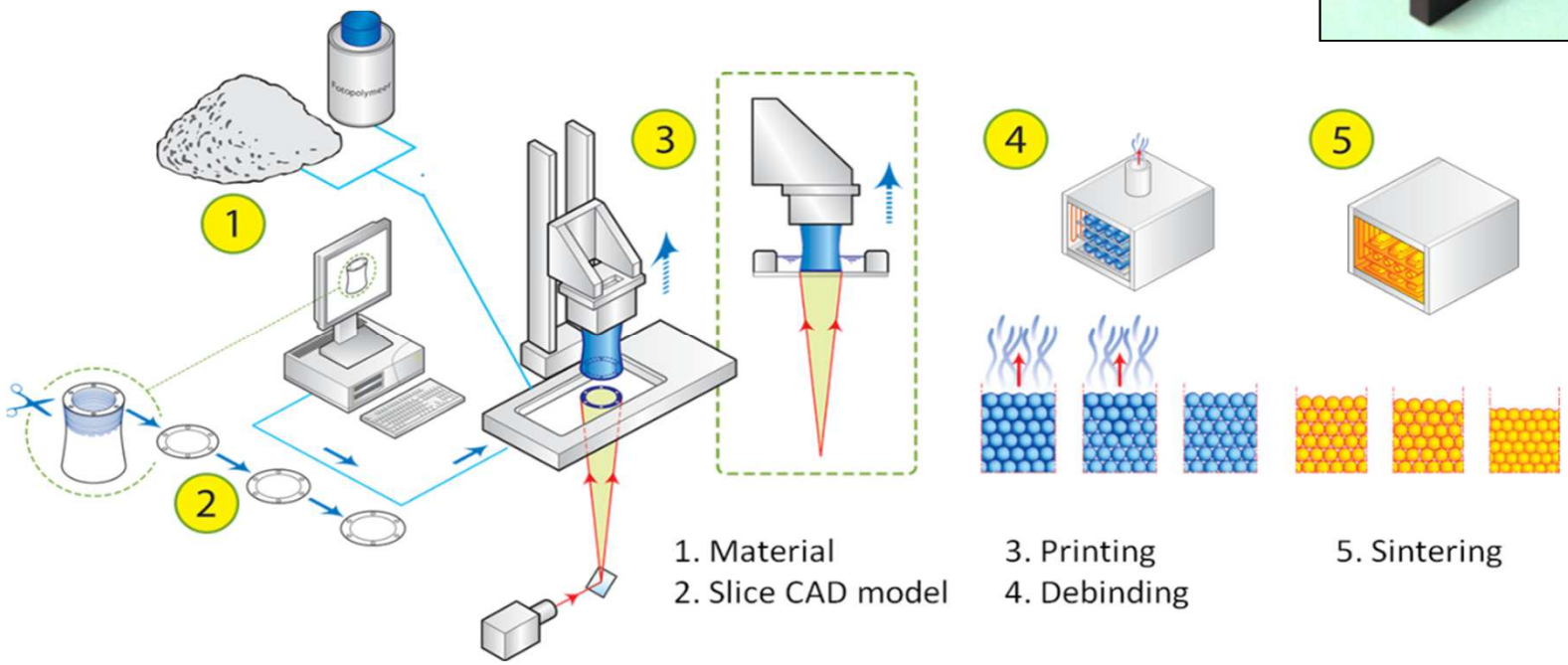




DLP (of Metals) basic proces

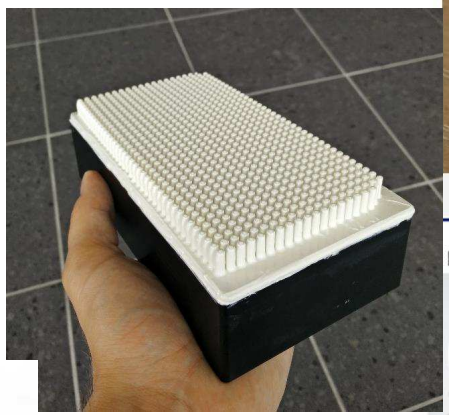
- Indirect, slurry based process

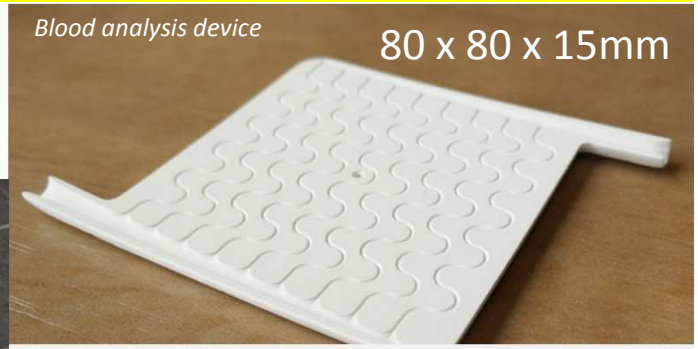




“Proven” Technology for oxidic ceramics

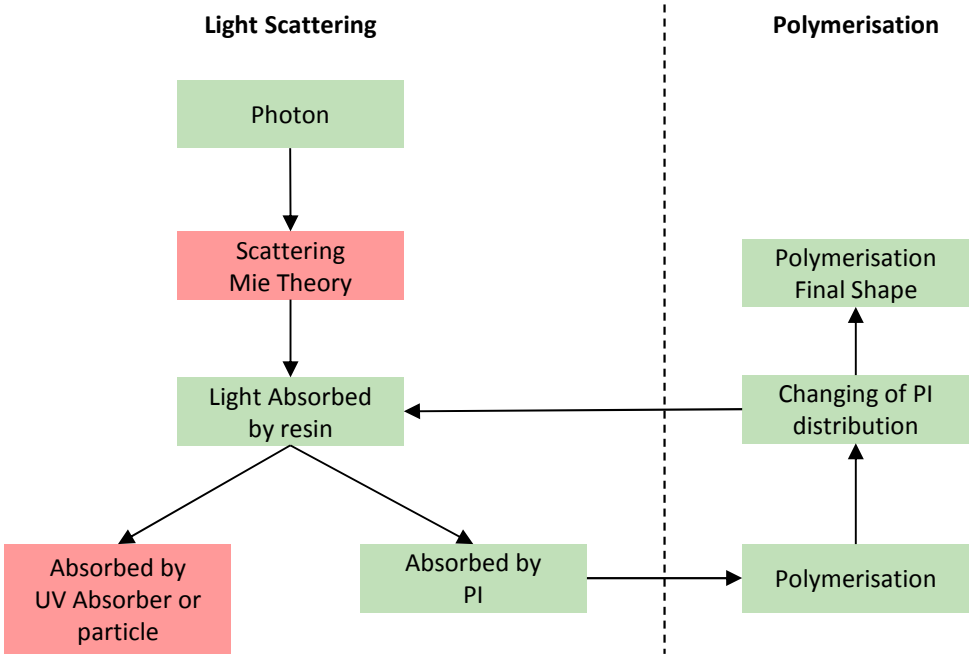
- Ceramic Materials
  - Al_2O_3 & ZrO_2
- High Quality,
  - small features,
  - accurate details
  - low roughness

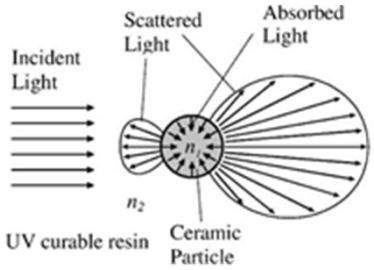


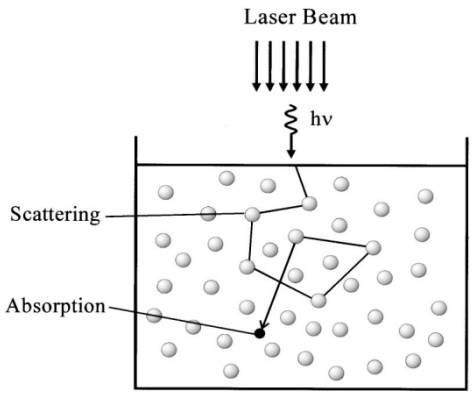


Limitating material properties

- Absorbtion & Light Scattering





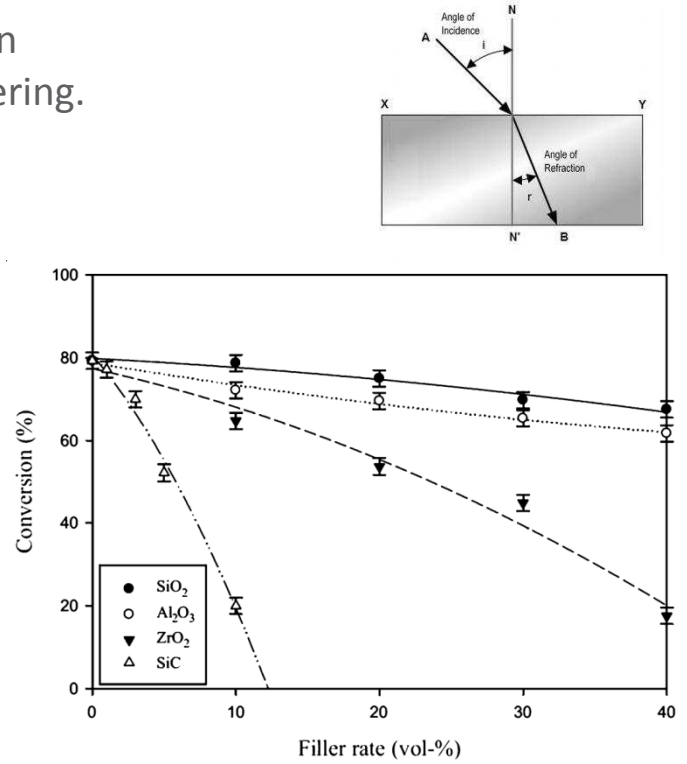


Mismatch in refractive Index

- The higher refractive index difference between particle and resin, the stronger the light scattering. (Less cure depth)

More dificult to cure

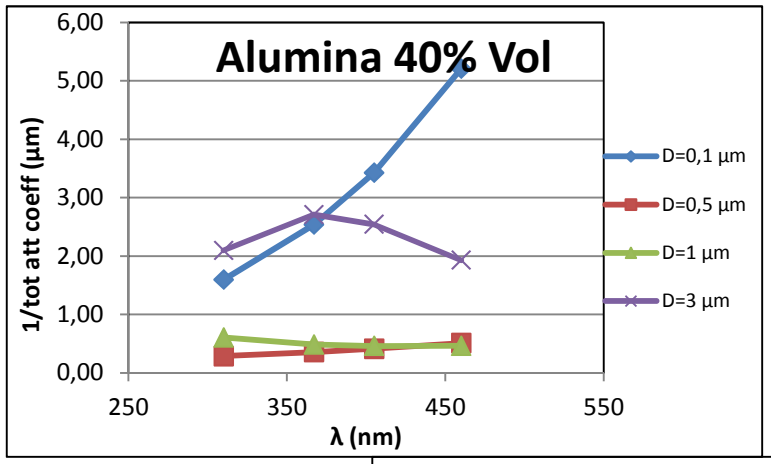
Material	Refractive Index n @ 437 nm	Im. Refractive Index n
Resin	1,46	0
SiO_2	1,47	0
Al_2O_3	1,7	0
ZrO_2	2,25	0
SiC	2,69	0,7
Steel	2,48	2,6
W	3,41	2,6

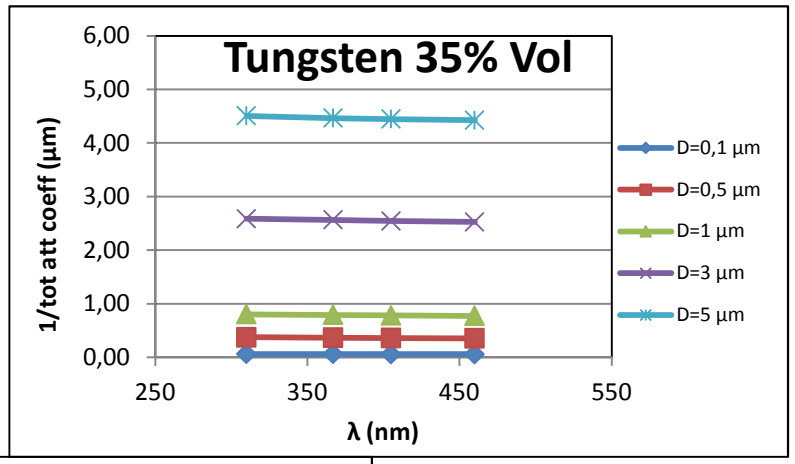


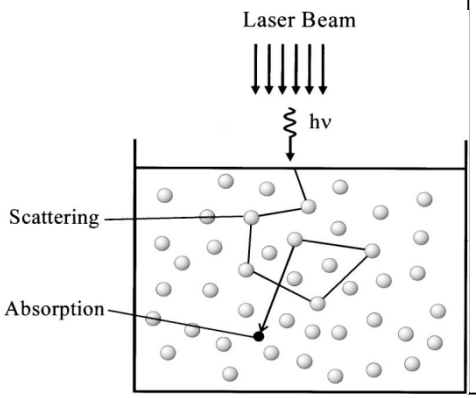
Influence of the refractive index and solid loading of ceramic filler on the polymerisation conversion of a acrylate filled resin

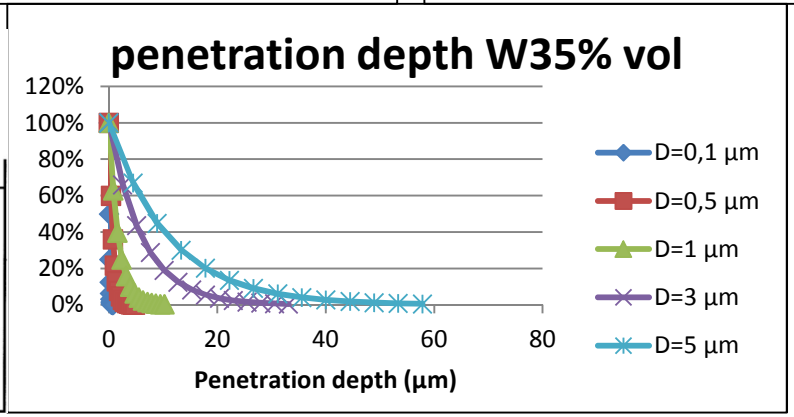
** Additive Manufacturing of Ceramics: A Review – J. Deckers*

MIE scattering



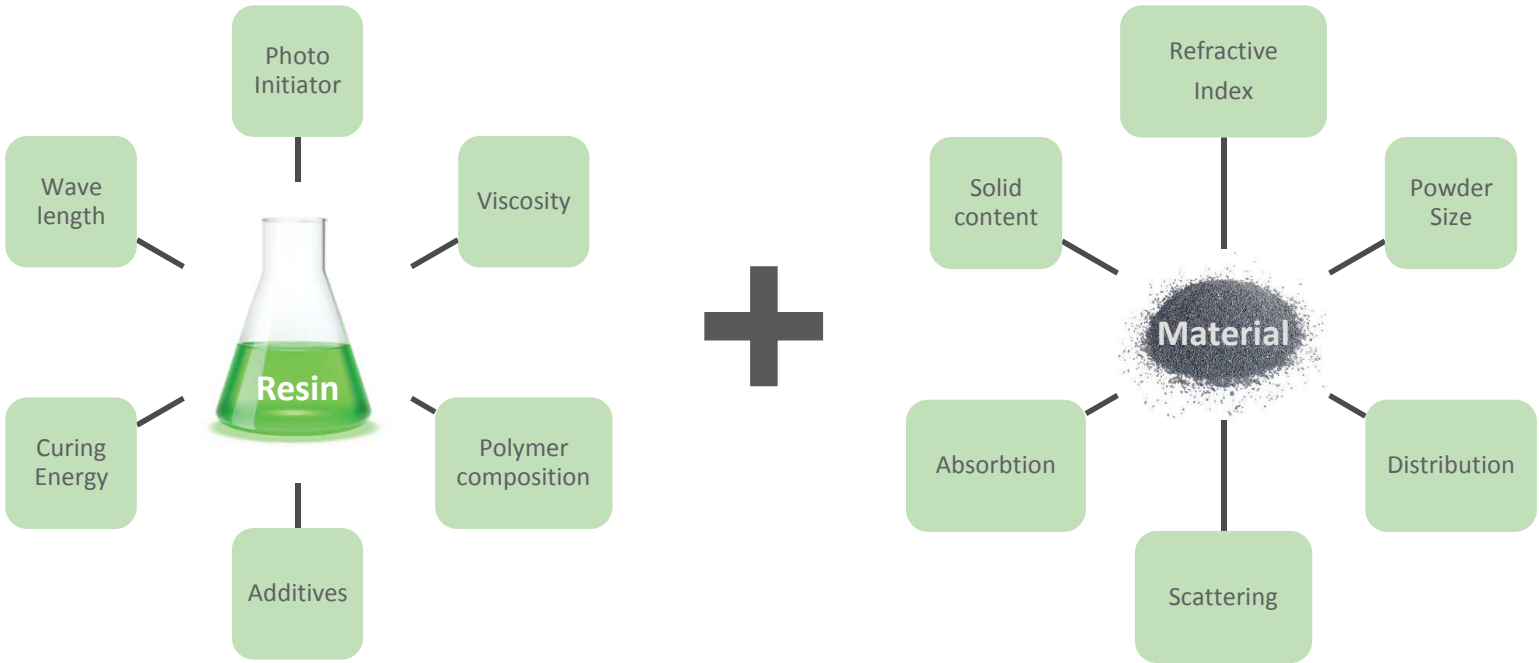






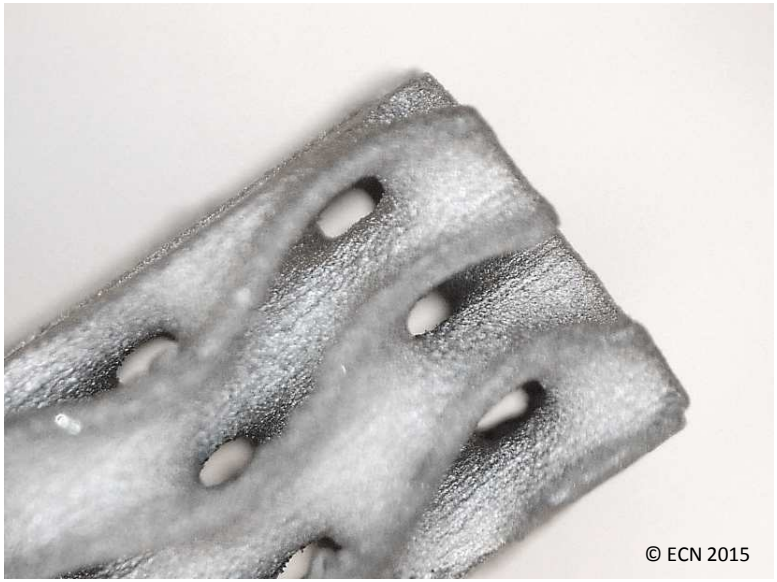
To be succesfull…

- Preparing a “dedicated” slurry to match your process is key.



316L gyroid

- Sintered 316L part
  - Size: 5x5x10 mm

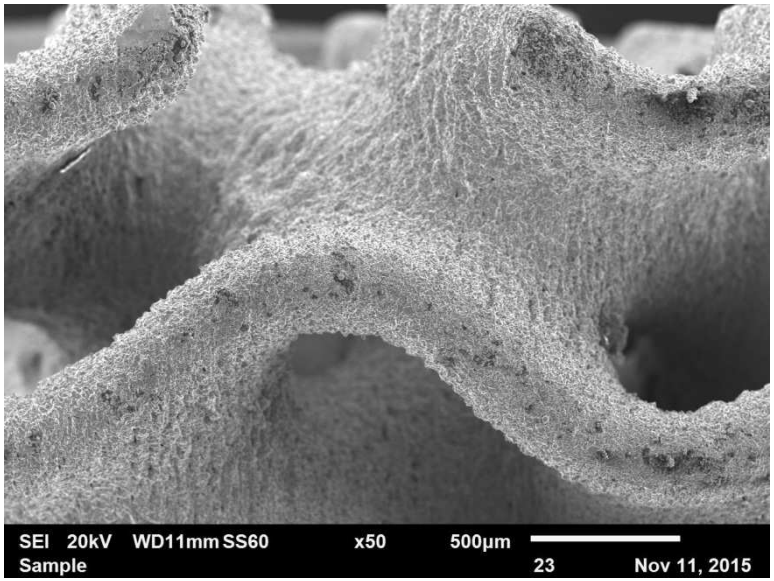


Detail of 3D printed geometry - sintered

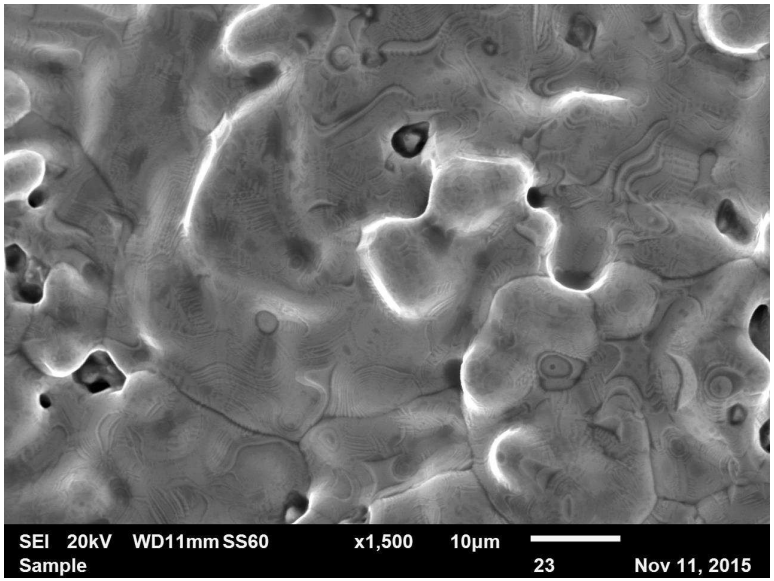
3D printed geometry - sintered

316L gyroid

- Sintered 316L part
  - Micro Structure

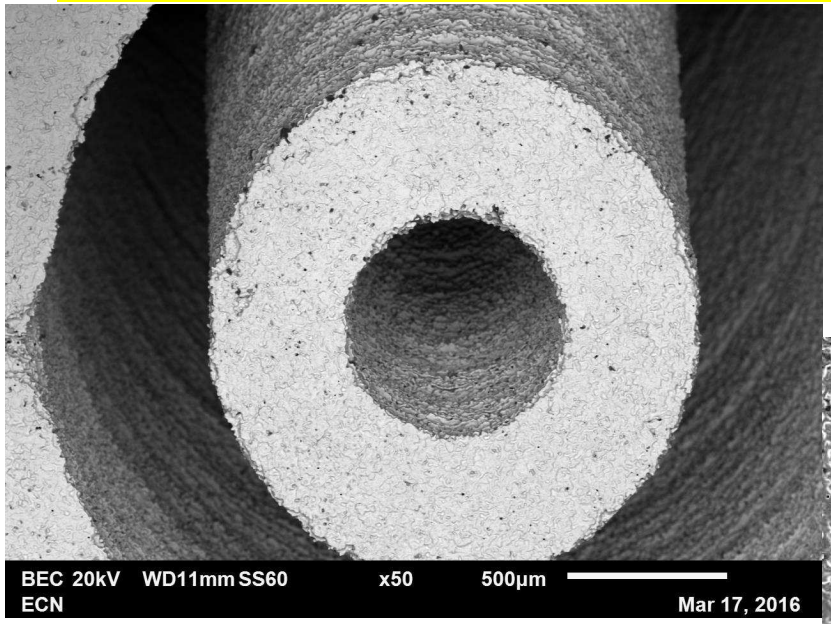


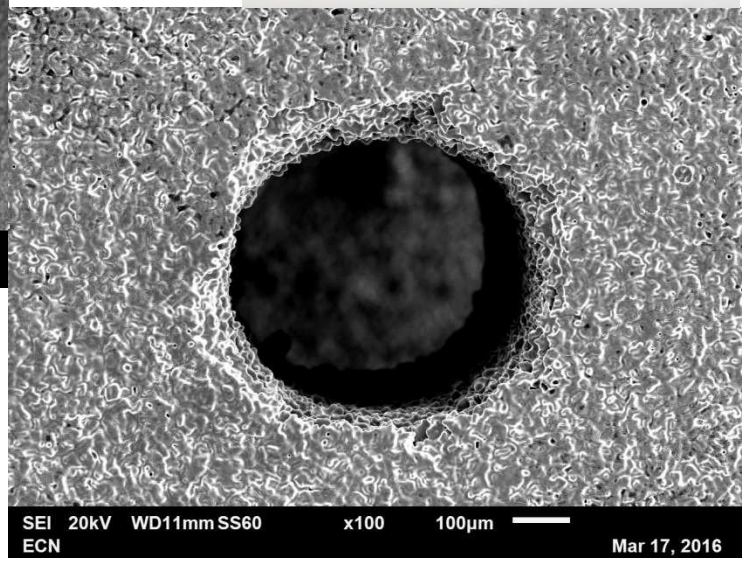
Detail of 3D printed geometry - sintered



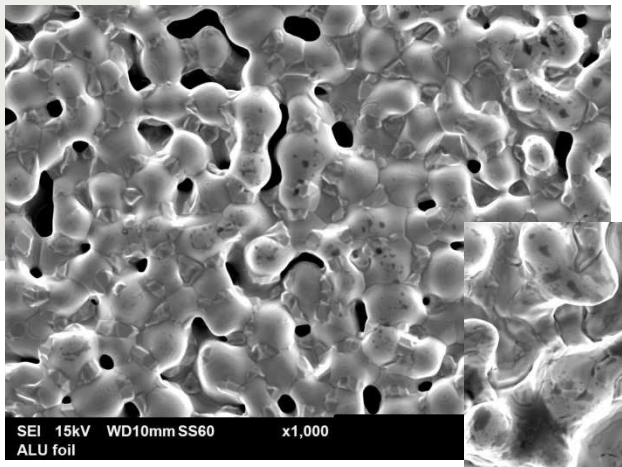
3D printed geometry - sintered

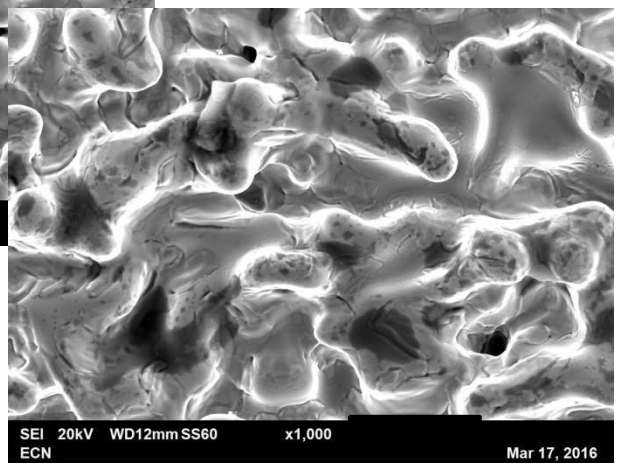
Printed details





Sintering process 316L





Higher sintering temperature

Comparison with other AM techniques

- Without post processing
  - Perpendicular to build direction.

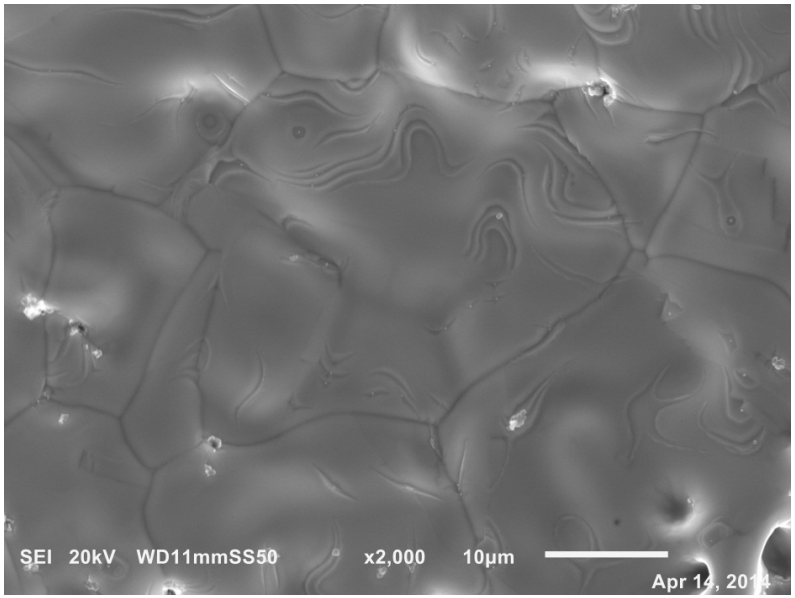
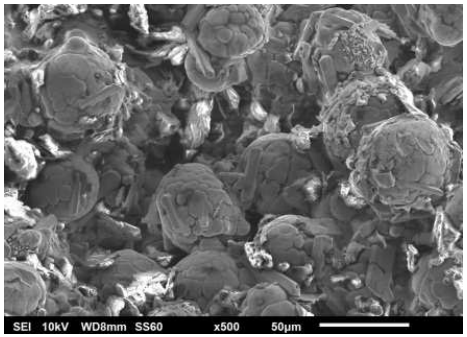
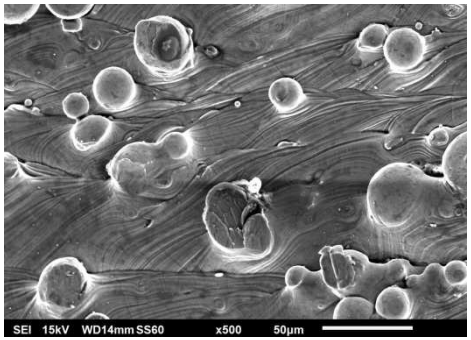


Photo Polymerisation 316L Sintered - ECN
(Indirect Process)



Binder Jet – ExOne
(Indirect Process)



Powder Bed Fusion
(Direct Process)

Metal Printing ECN: indirect and also direct

Indirect method

Pro

- *Isotropic high quality structure*
- *Complex features possible*
- *Low cost printing equipment*

Contra

- *Separate densification process*
- *Shrinkage*
- *Build speed lower than ceramics*

Patents

- *Pending 3x*
- *Assigned 1x*

Direct method

Pro

- *Direct*
- *Low stress compared to SLM*
- *Finer Features / channels possible*

Contra

- *Expensive equipment, comparable to Vat Photo Polymerisation equipment*
- *Anisotropic microstructure*

Patents

- *Pending 1x*

SiC and (Si_3N_4)

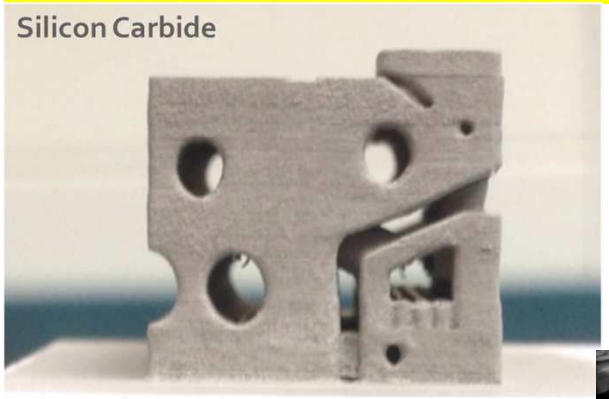
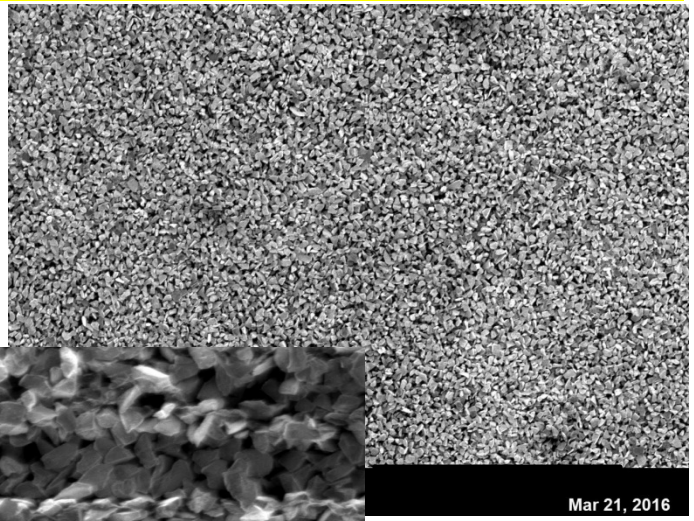
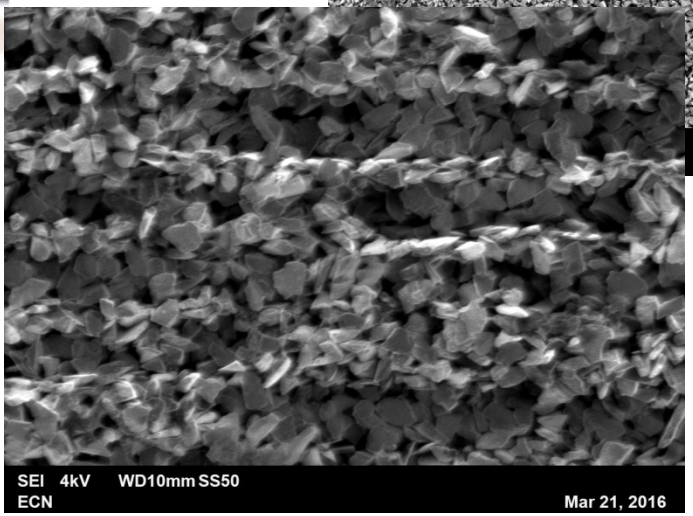


Photo Polymerisation SiC- ECN





SiC after de-binding- ECN

Conclusion

- AM processes for Metals by
  - Liquid solidification (melted droplets)
  - (spot) welding (selective laser melting)
  - Thermal spraying (preheated powder deposition / impact)
  - Sintering

- Best AM metals by sintering!

  A production process comparable to PM Steel production and /or Metal Injection Moulding possible by VAT polymerization / DLP even for Metals

- AM of non oxidic ceramics (SiC and Si_3N_4) feasible by DLP

- Production speeds of cm / hour (full area) are realistic

Thank you for your attention

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