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ÉCOLE POLYTECHNIQUE DE LOUVAIN
iMMC Institute of Mechanics, Materials and Civil Engineering
CRM GROUP

Critical assessment of the hydrogen uptake during the powder-bed laser 3D-printing of Al-Si grade

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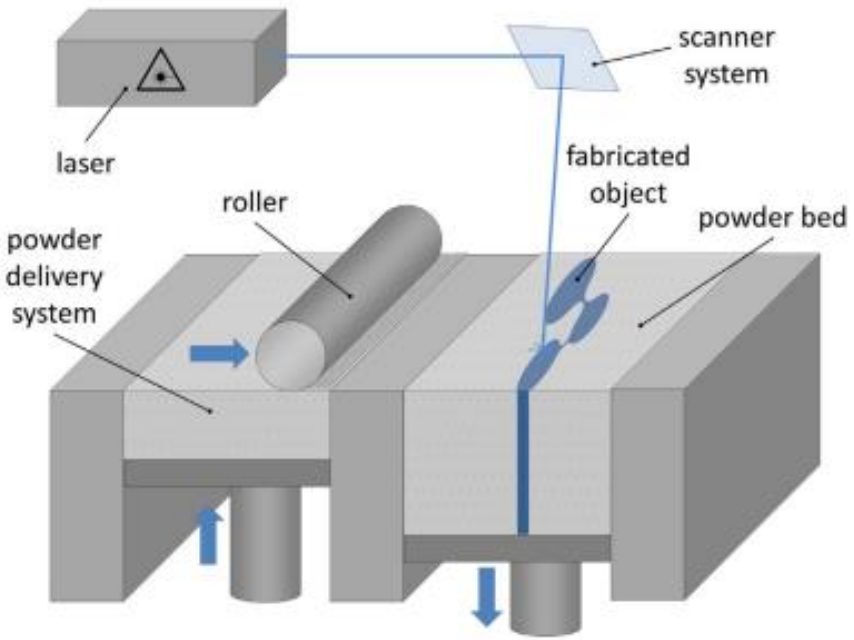
3rd Workshop on Additive Manufacturing, May 28th 2018

The new paradigm of additive manufacturing



Leitz et al., 2016

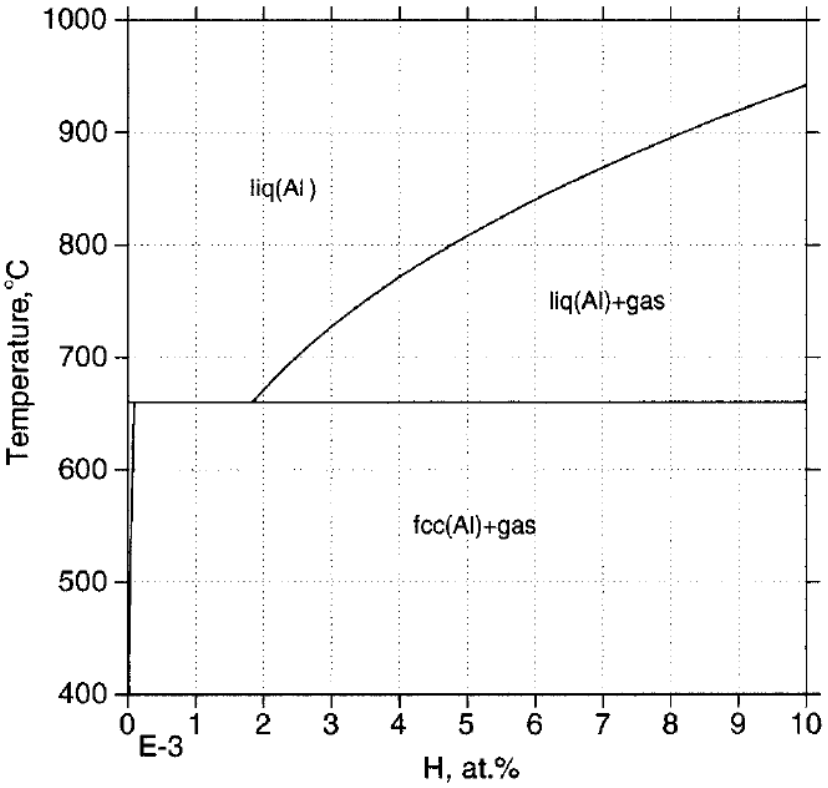
Powder-bed based → specific issues related to the huge specific area

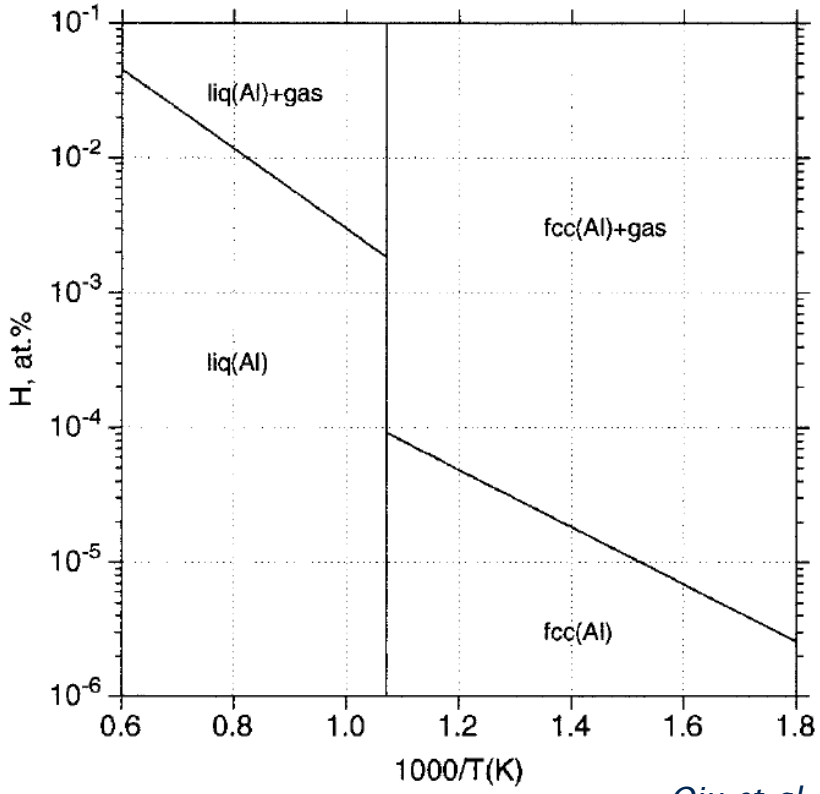
Solidification / welding process → specific defects like porosity

The hydrogen issue in aluminium alloys

Concerns about hydrogen embrittlement in aluminium alloys

- Hydrogen significantly soluble in liquid Al
- Large drop of solubility in solid Al → segregation



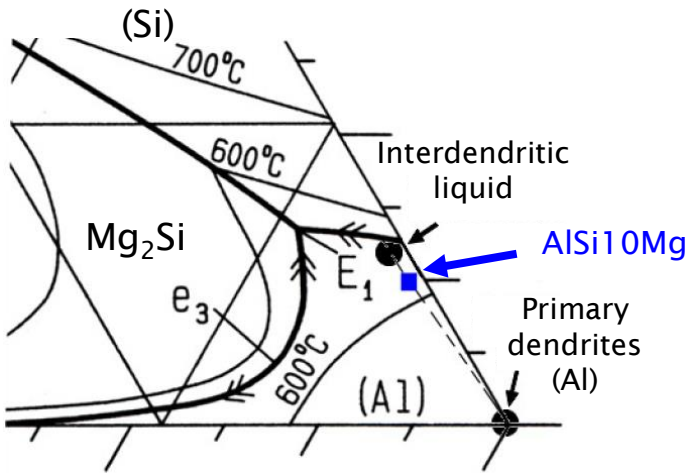


Qiu et al., 2004

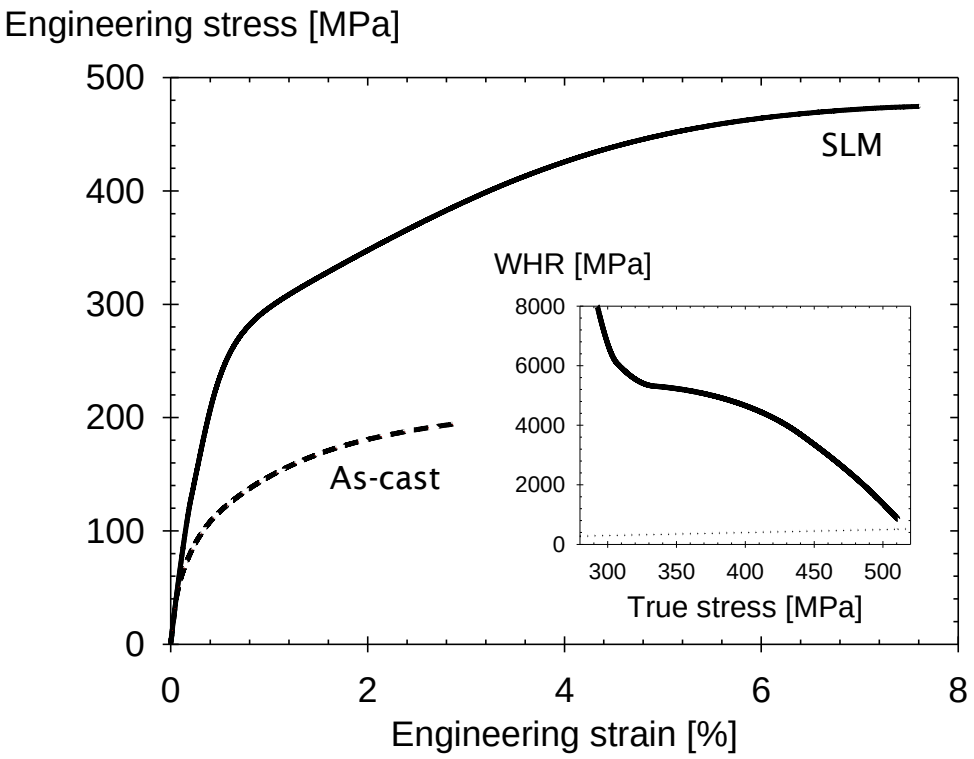
Al alloys for additive manufacturing

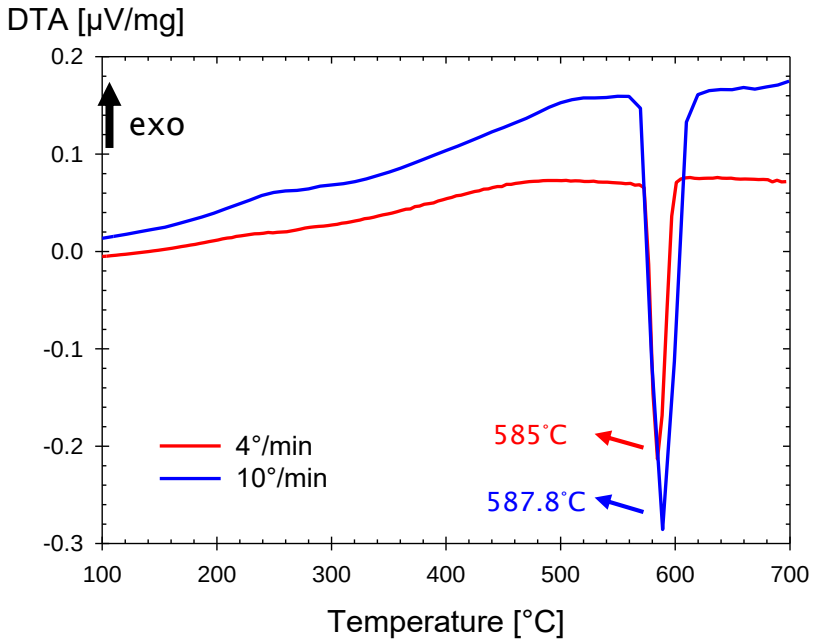
AlSi10Mg

	Al	Si	Mg	Cu	Fe	Mn	Zn
AlSi10Mg powder	Bal.	9.9	0.45	<0.01	0.1	<0.01	<0.01
AlSi10Mg SLM	Bal.	9.9	0.47	<0.01	0.12	<0.01	<0.01
AA4420	Bal.	9.87	0.52	0.02	0.15	<0.01	0.12

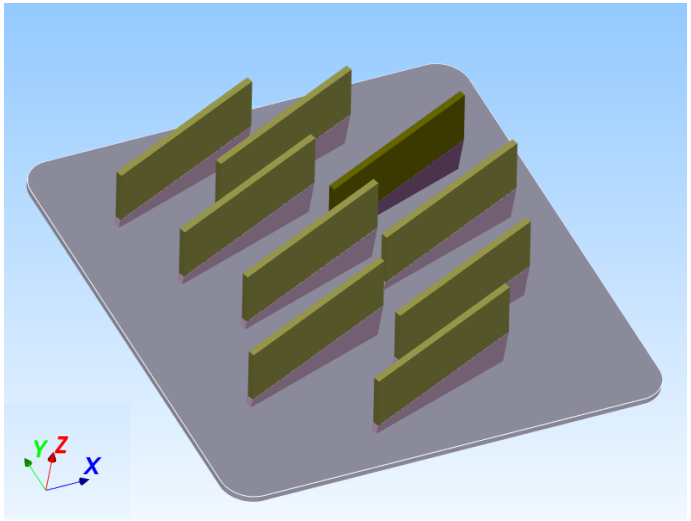


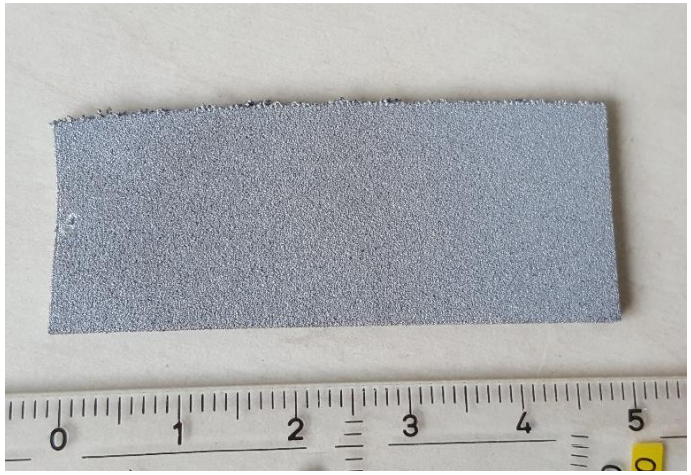
(G Petzow et al., ASM Int., 1993)



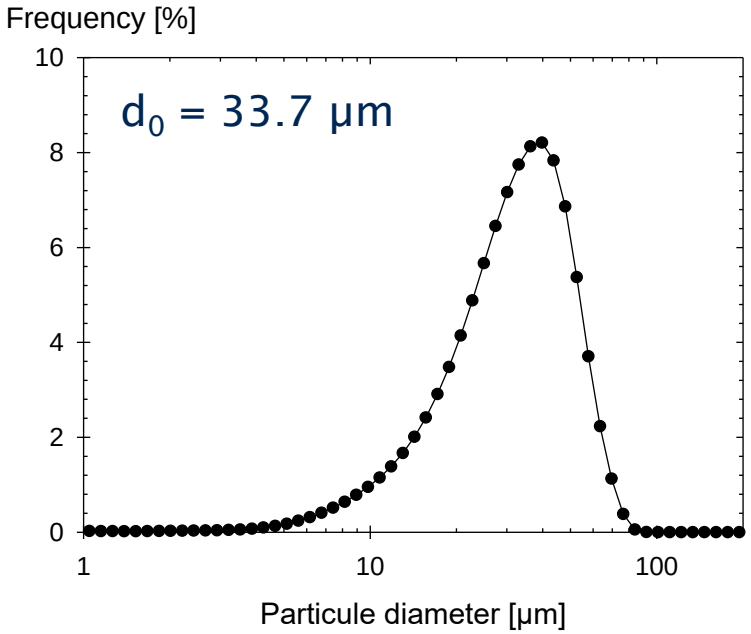


3D printing of samples





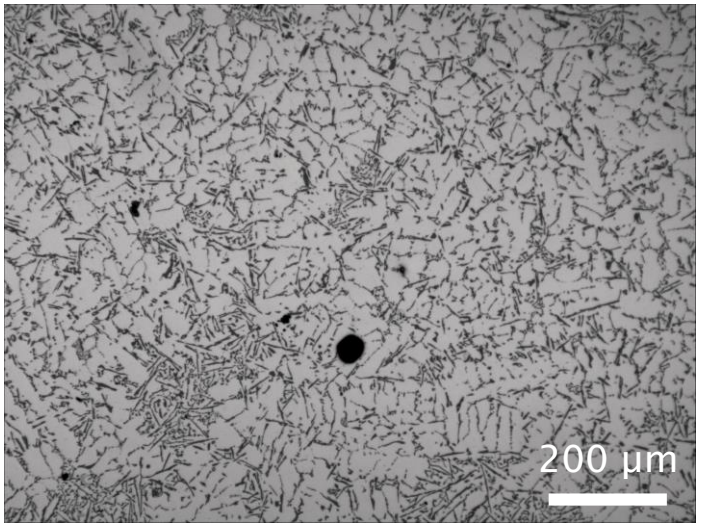
- Close to optimised processing parameters
- New powder, room T
- Powder ranging from 2 to 90 µm

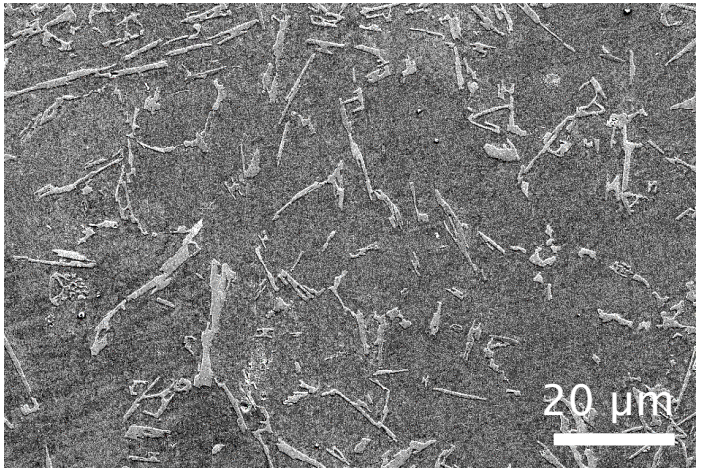


	Relative bulk density [%]
AlSi10Mg as-built	98.9
AA4420 as-cast	99.06

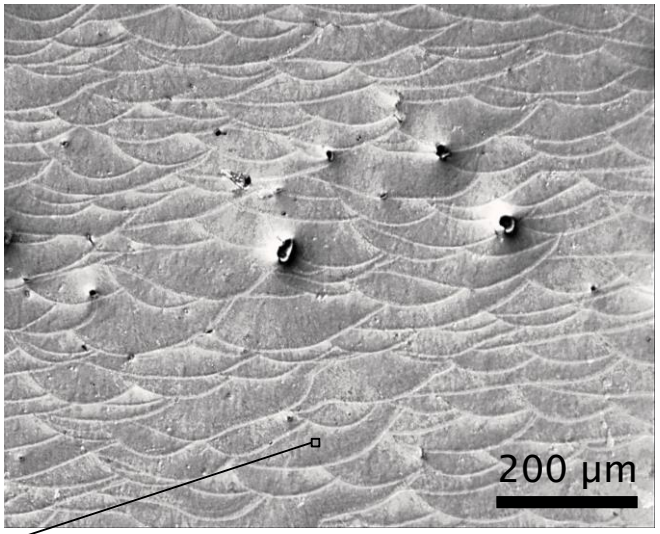
As processed microstructures

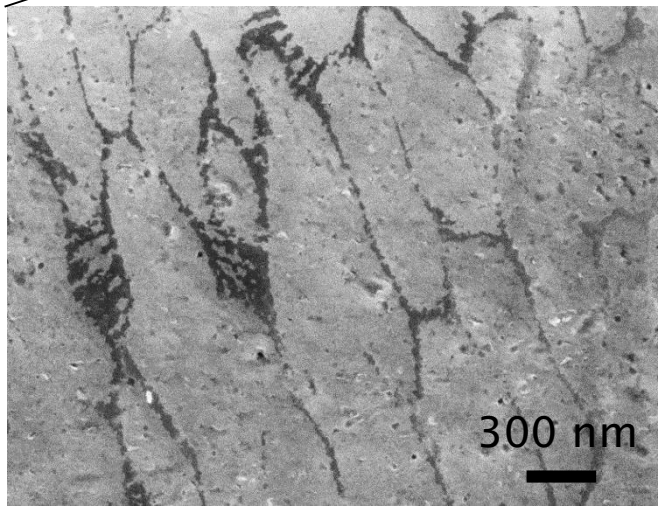
As-cast



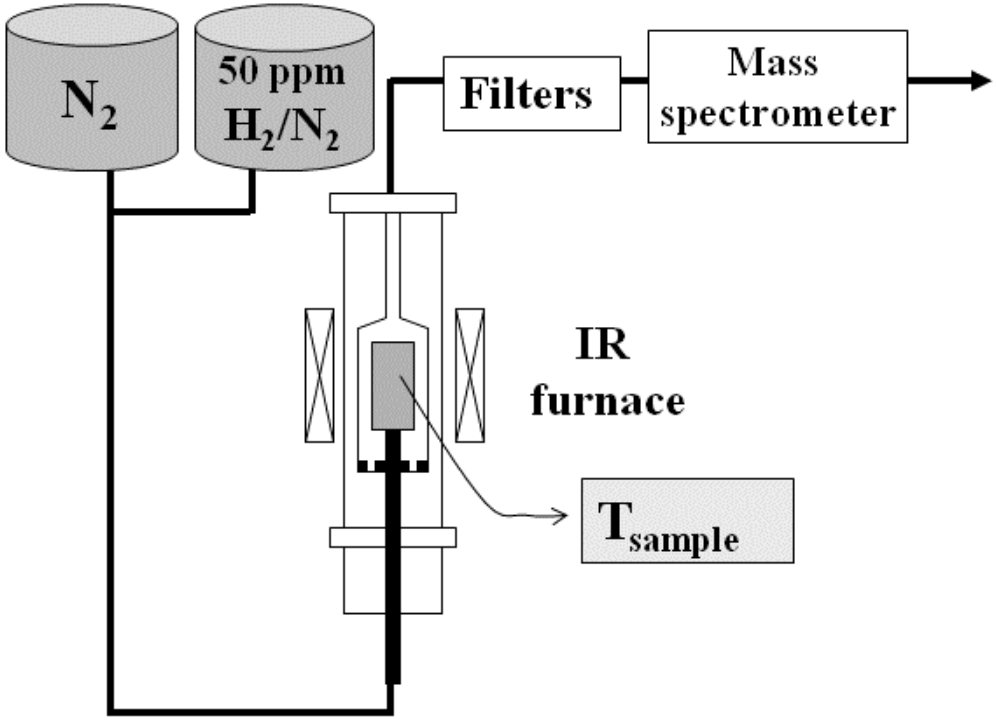


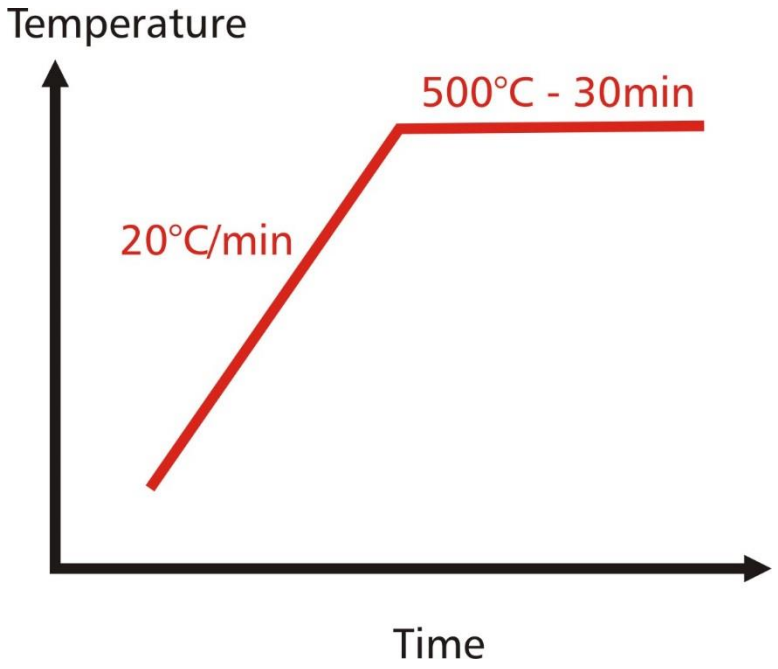
As-built SLM



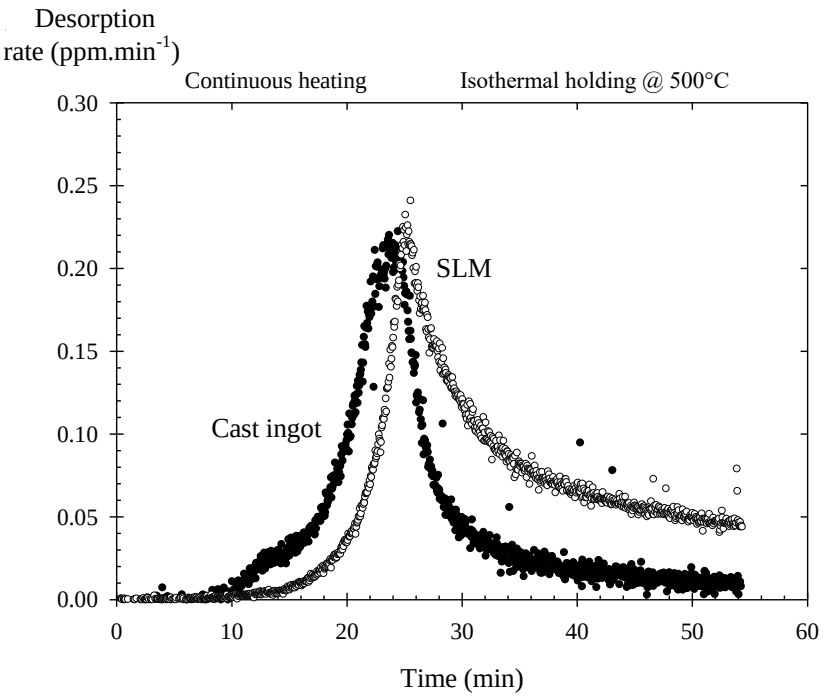


Thermal desorption analysis

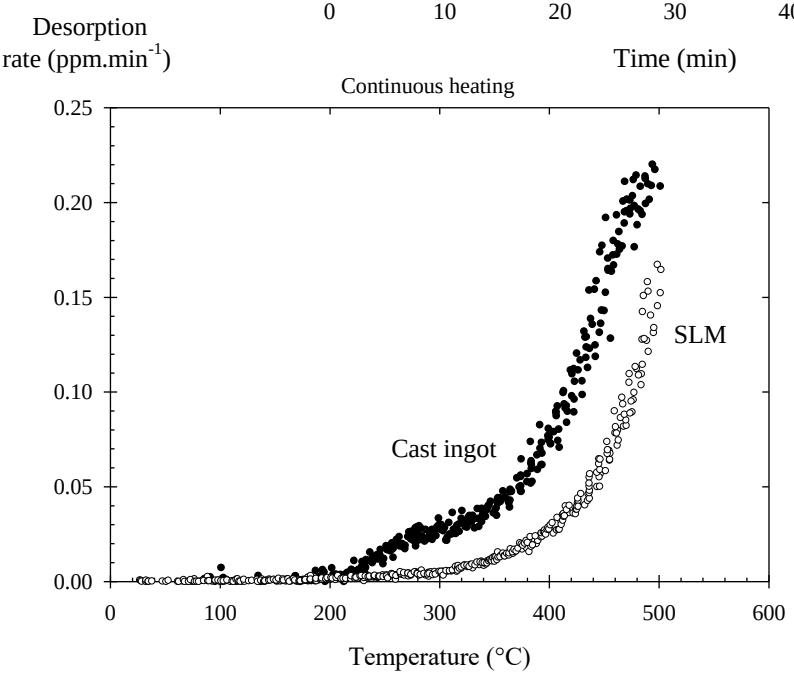


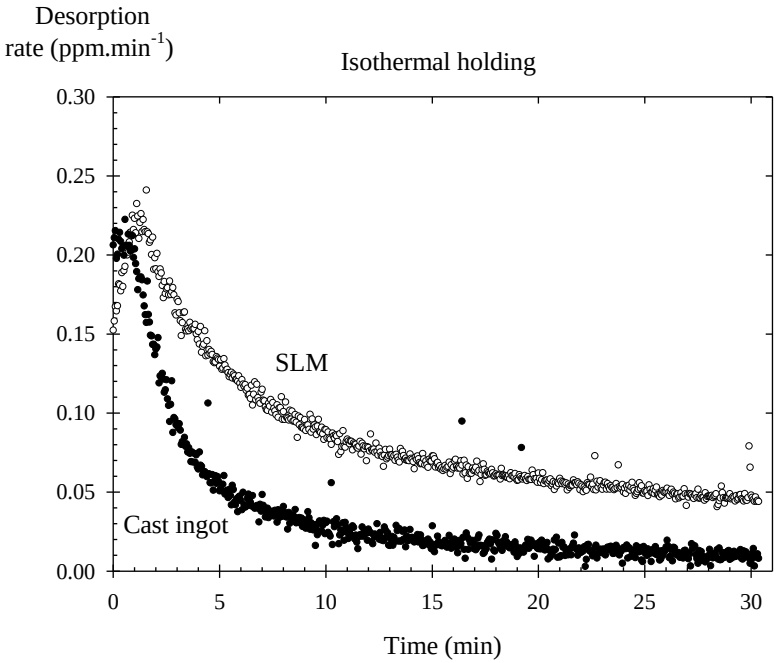


Influence of processing route



	Released H_2 (wt.ppm)
SLM	2.99
Cast ingot	2.02



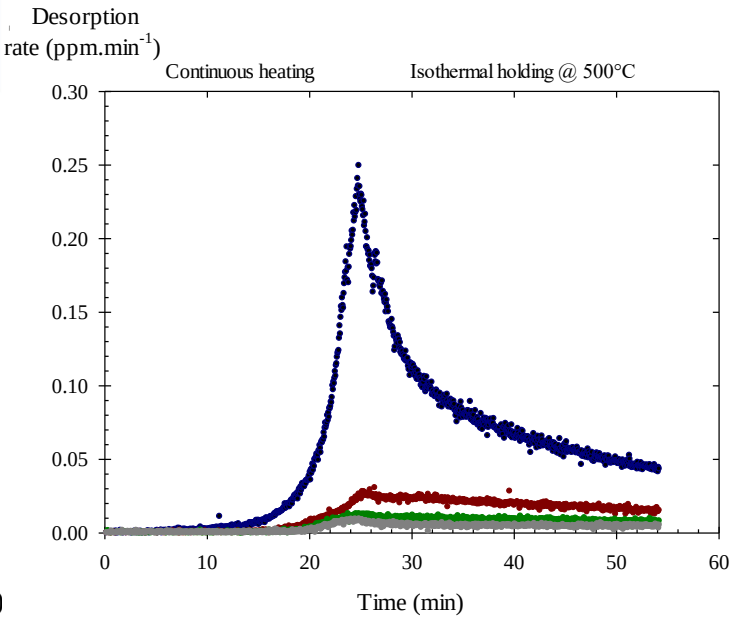


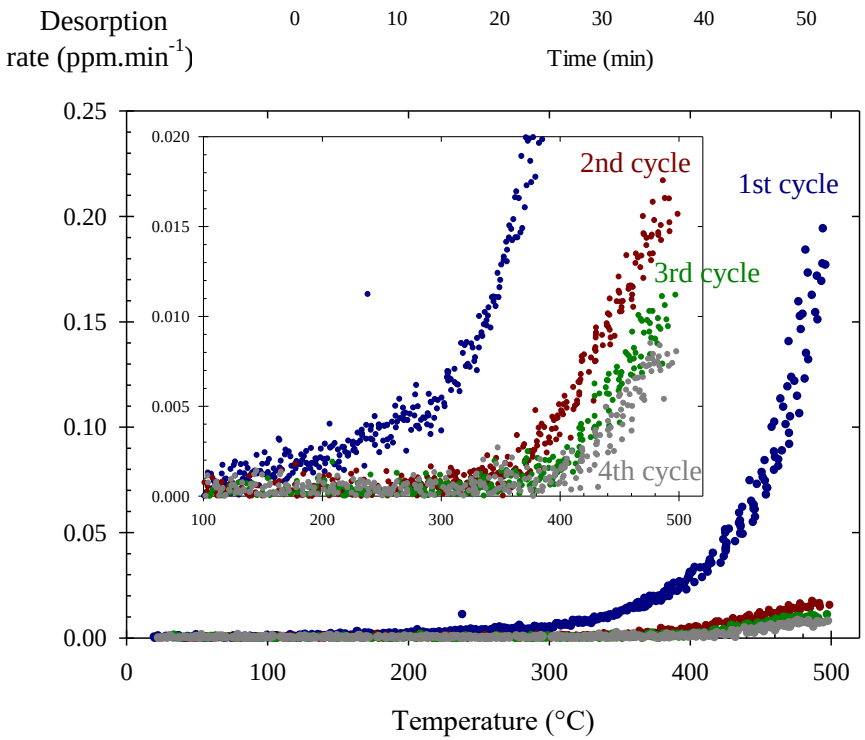
Several cycles

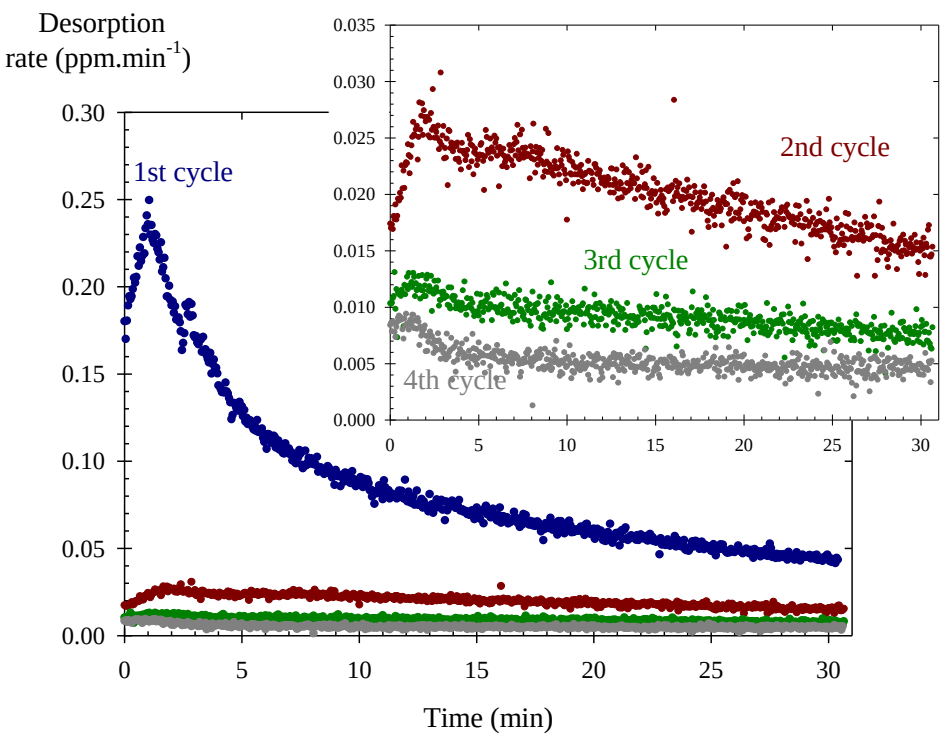
	Released H_2 (wt.ppm)
1st cycle	3.1
2nd cycle	0.7
3rd cycle	0.3
4th cycle	0.2

(continuous cycles under controlled atmosphere)

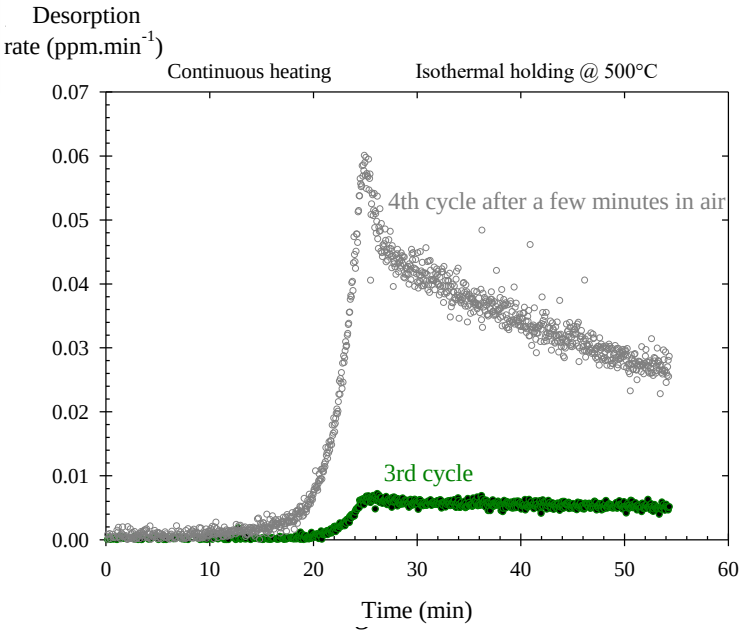
Total content of H_2 (combustion): 6.1 wt.ppm



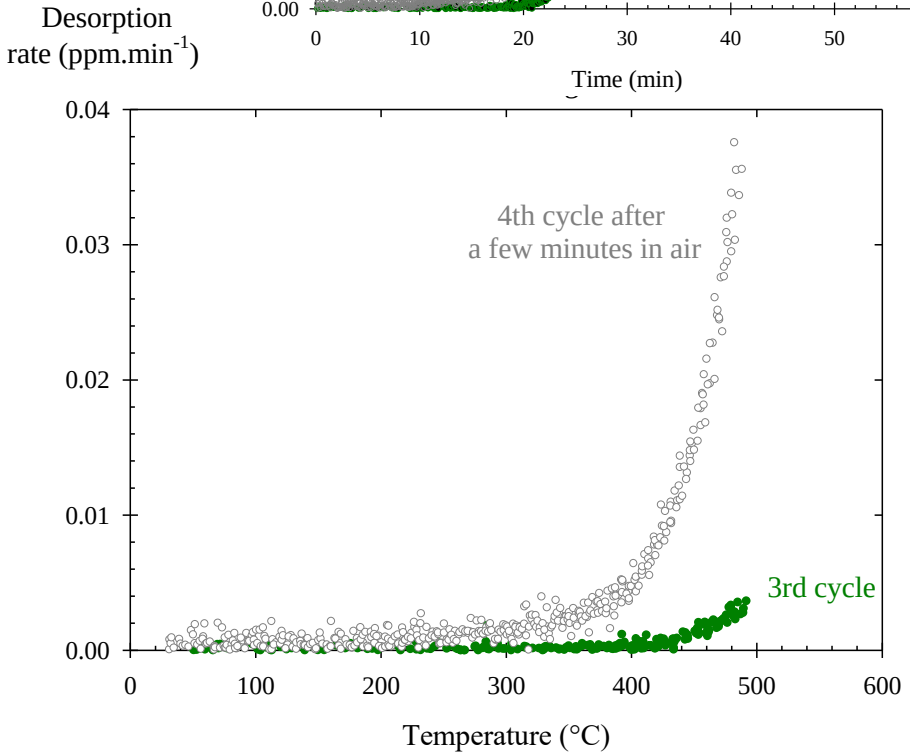


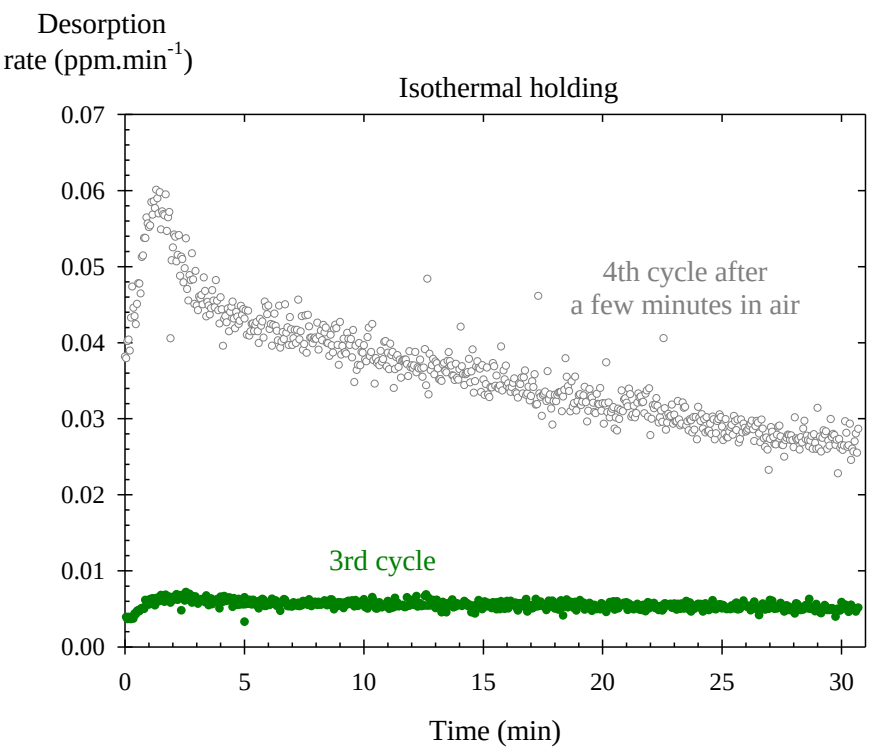


Influence of atmosphere



	Released H_2 (wt.ppm)
1st cycle	3.1
2nd cycle	0.7
3rd cycle	0.3
4th cycle	0.2
4th cycle after a few min. in air	1.21

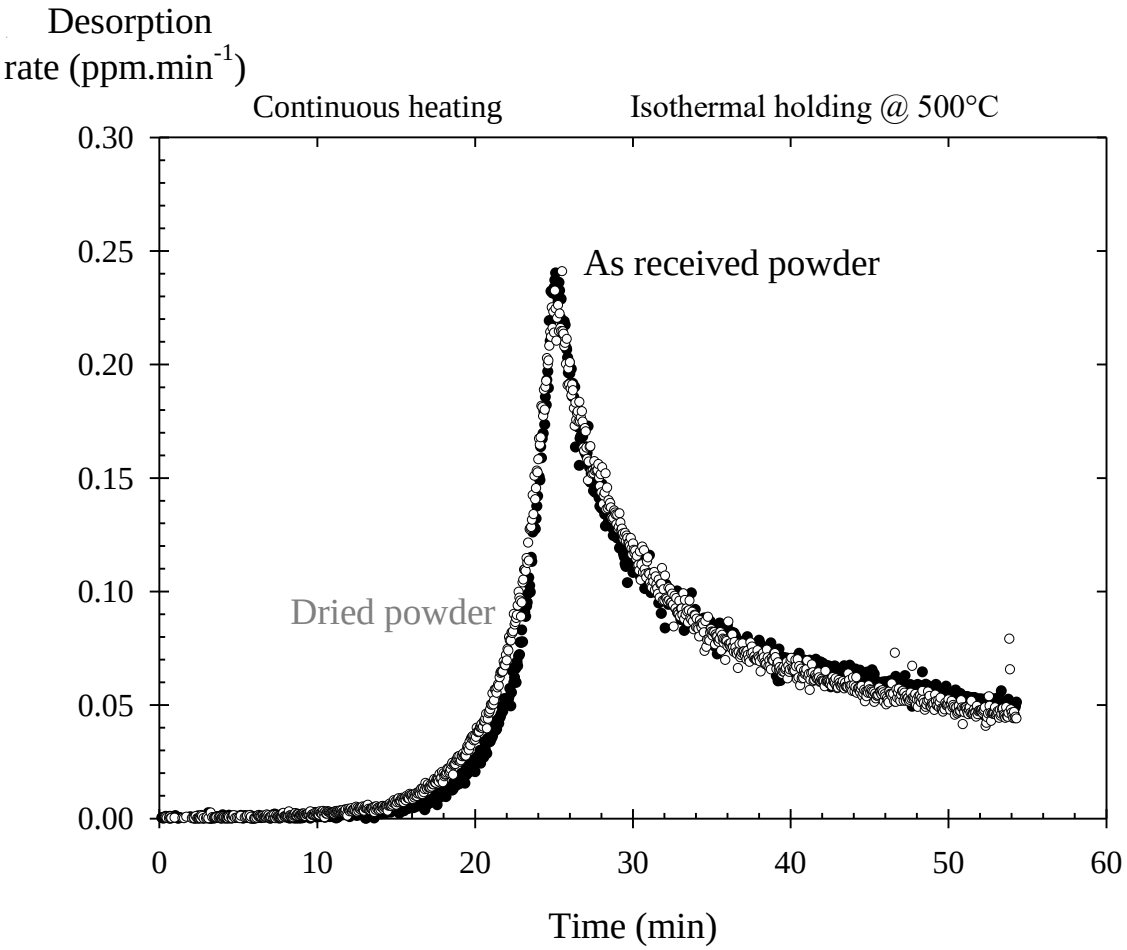




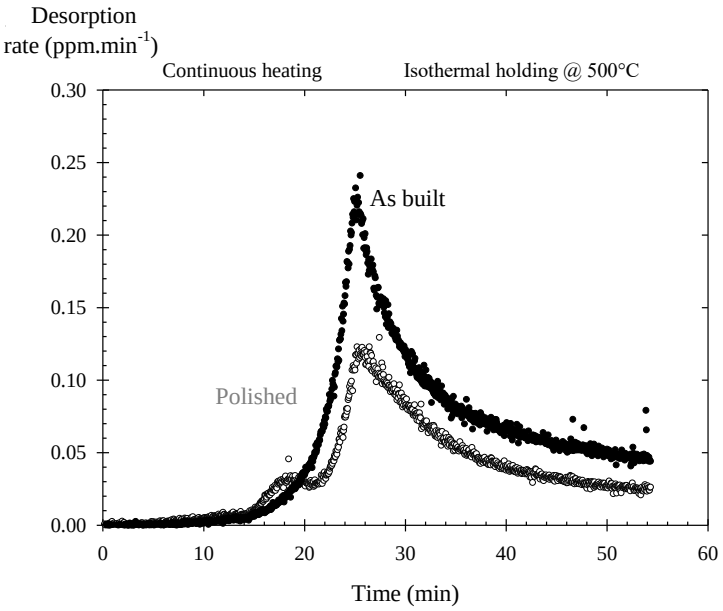
Influence of powder conditioning

Stoving conditions :

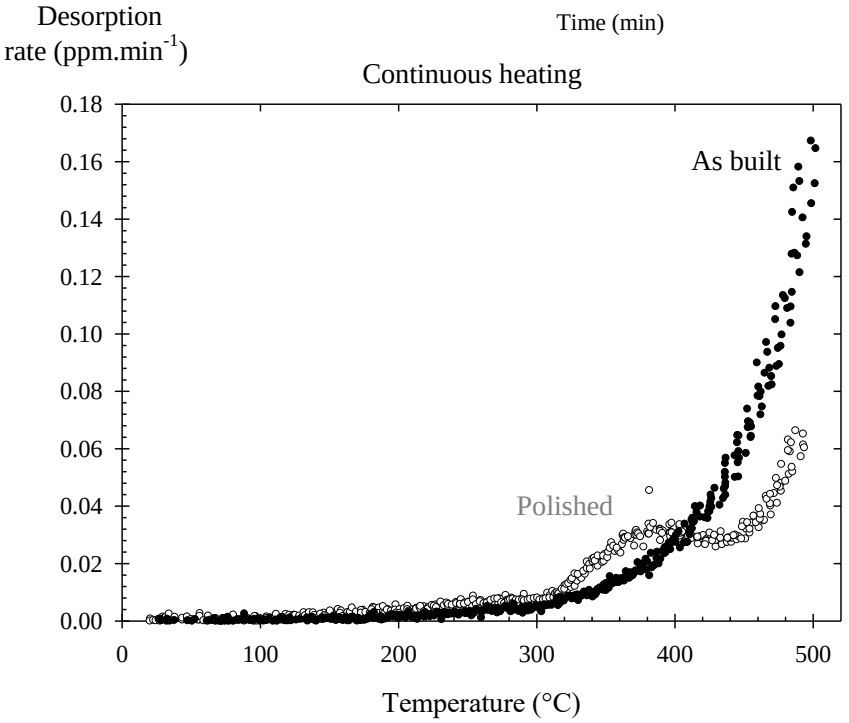
- Powder spread on silica plate, 100°C for 1h
- Also stoving of the tanks

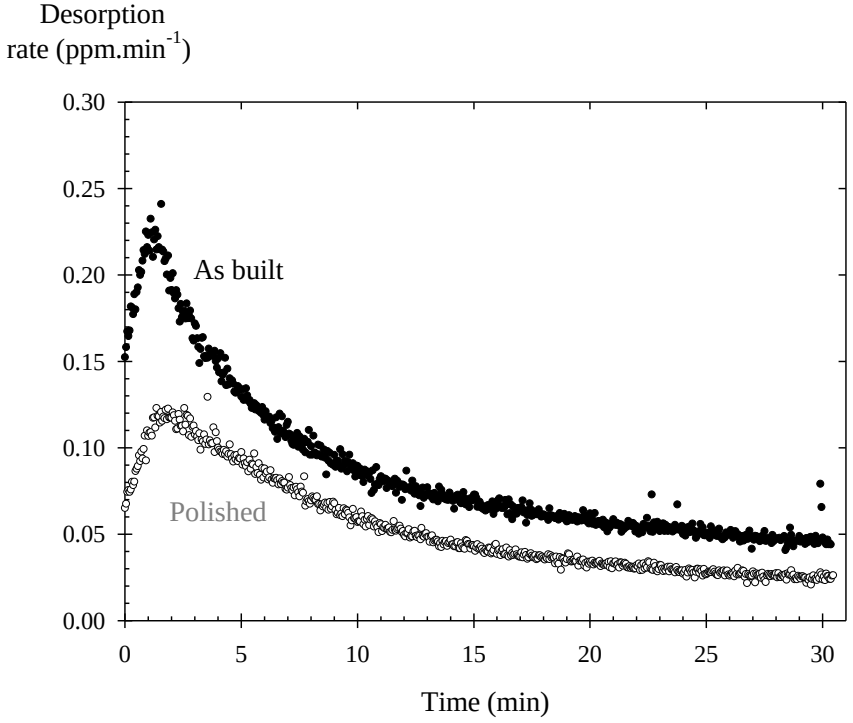


Influence of surface state

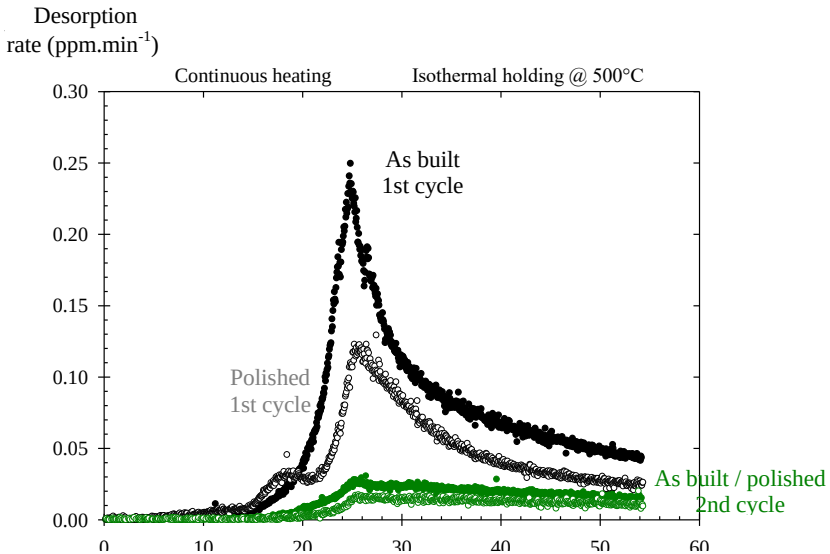


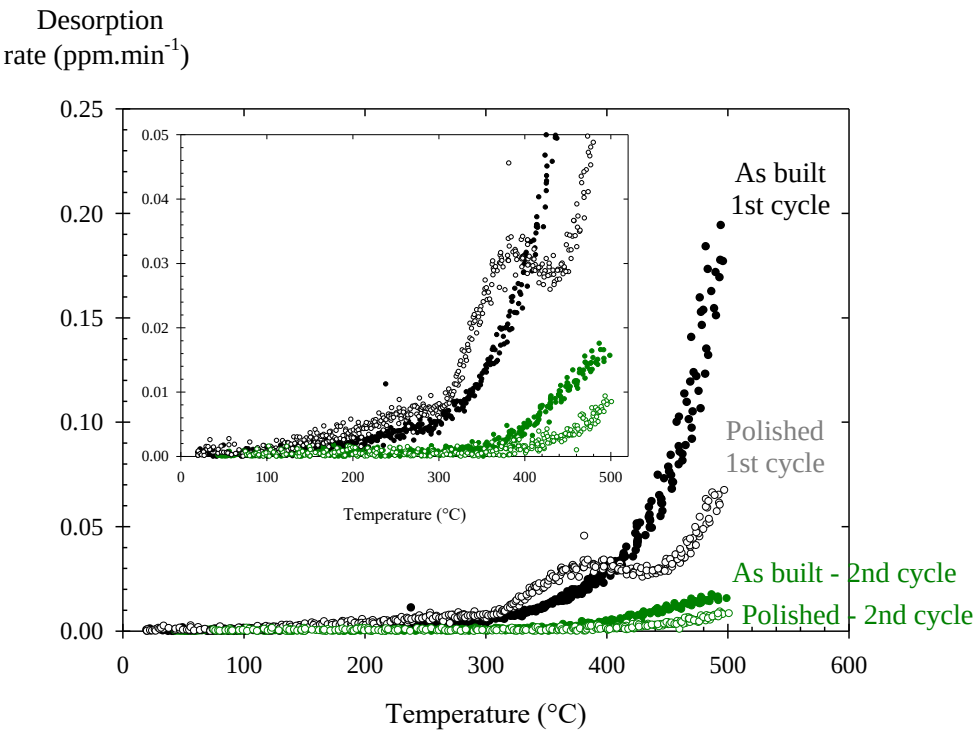
	Released H_2 (wt.ppm)
As built	2.99
Polished	1.89

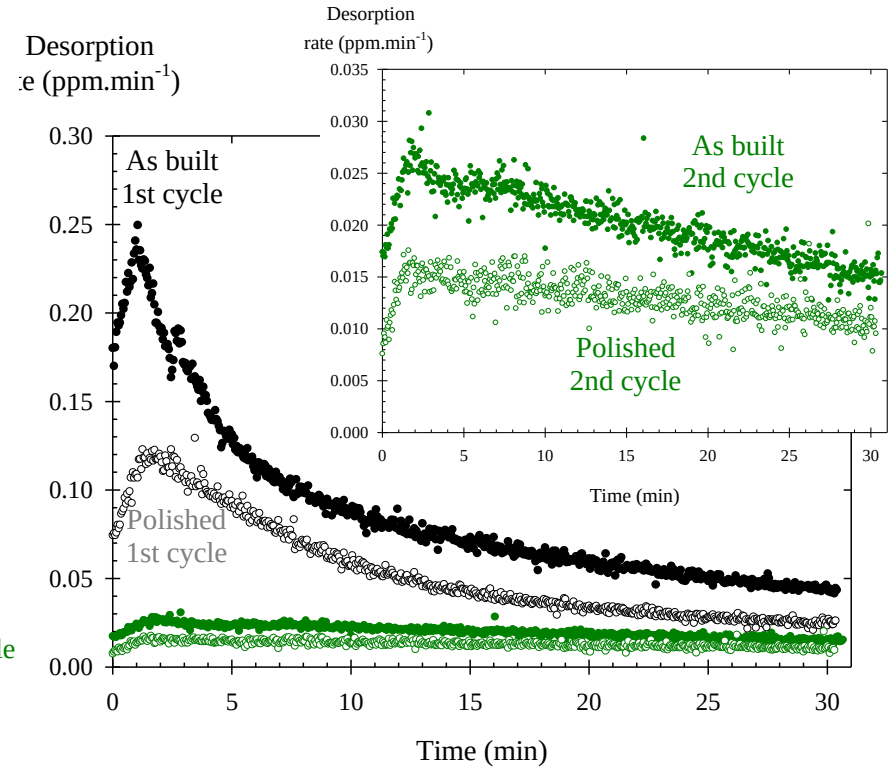




Influence of surface state

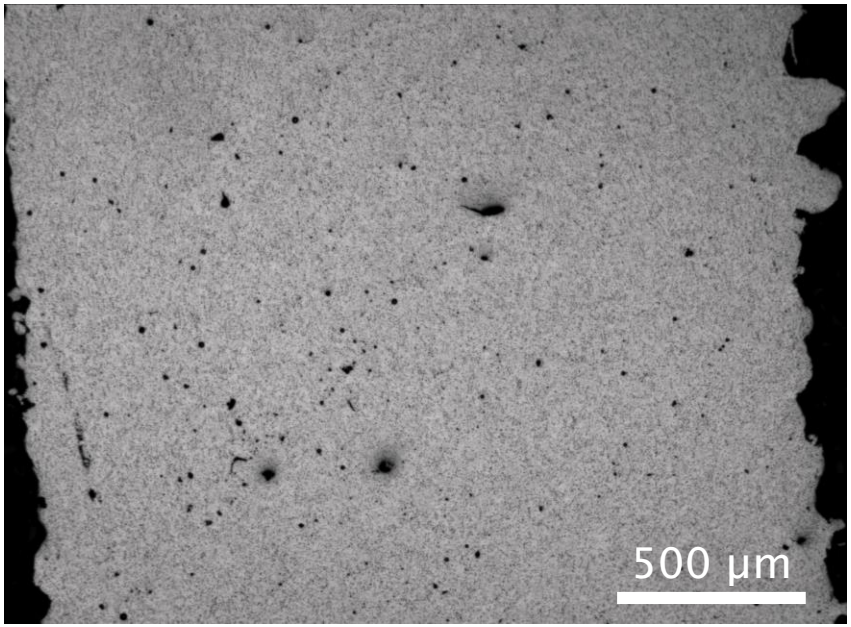






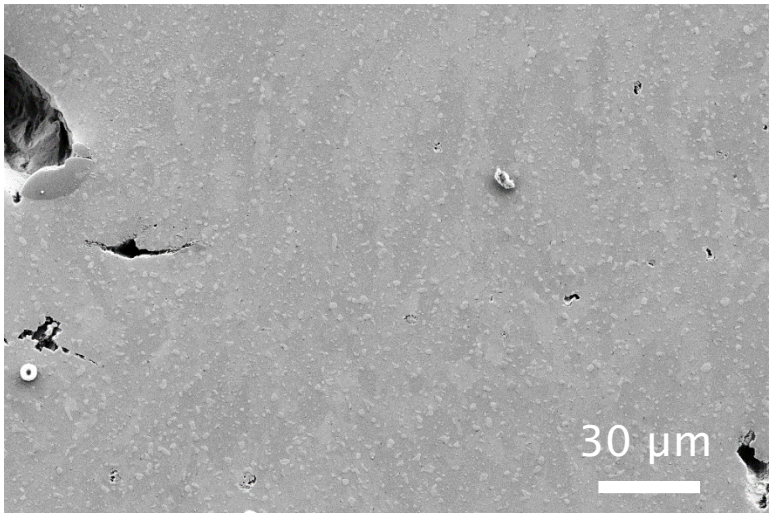
Evolution of porosity

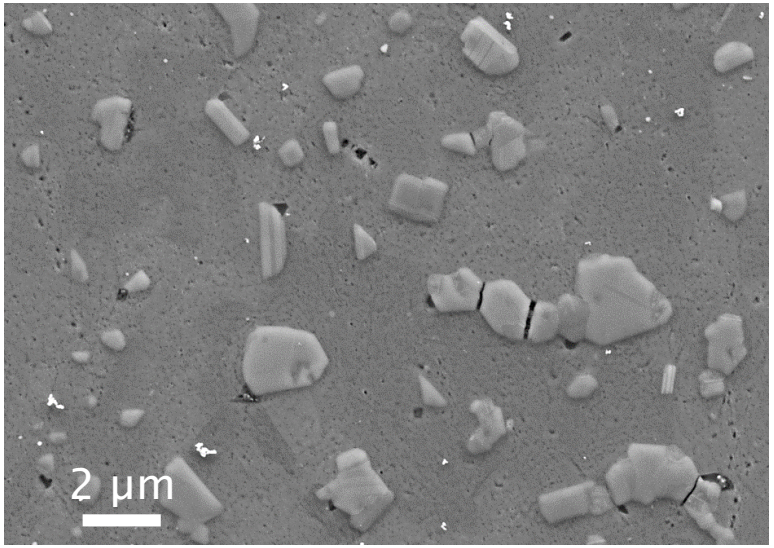
Global growth of the size of the porosity



	Relative bulk density [%]
as-built	98.9
after heat cycles	**98.24**
AA4420 as-cast	99.06

After 2 TDA cycles at 500°C





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Summary

- Presence of a large amount of H2 in AlSi10Mg processed by powder-bed additive manufacturing
- Slow release even at high temperature
- Large influence of interactions with atmosphere
- No apparent influence of powder drying *(in the case of new batch of powder)*
- Large influence of the surface state
- Evolution of the porosity during heat treatment

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