FACULTY OF SCIENCES

DEPARTMENT OF SOLID STATE SCIENCES
CONFORMAL COATING OF NANOMATERIALS

Atomic layer deposition and X-ray characterisation of mirror coatings

Jorden De Bolle, Jolien Dendooven, Christophe Detavernier

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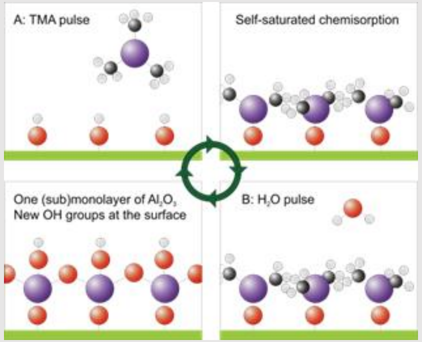
CoCooN
Conformal Coating of Nanomaterials

IRI project content

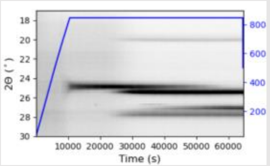
CoCooN
Conformal Coating of Nanomaterials

Amorphous coatings

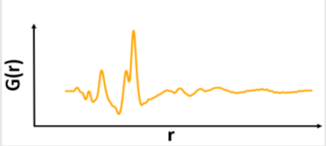
Deposition of amorphous coatings with ALD



X-ray characterisation of mirror coatings



In-situ XRD (collaboration with VCR&D)



PDF analysis (funded by IRI)

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Deposition of amorphous coatings with ALD

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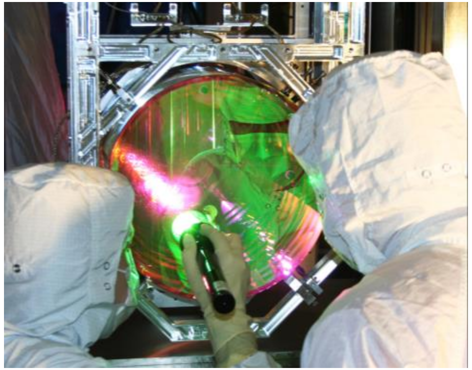
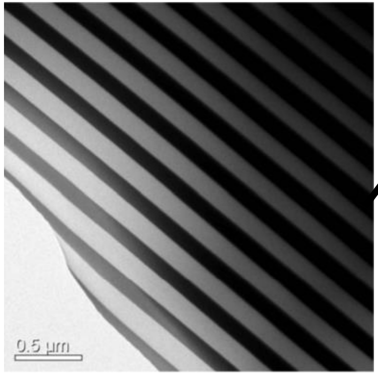
Why different deposition techniques

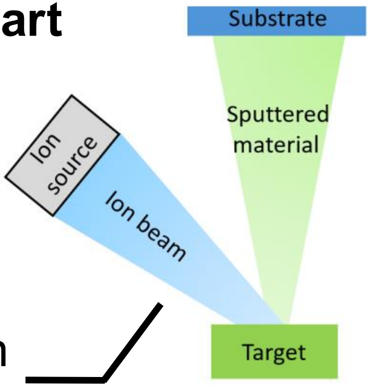




Current state-of-the-art

Alternating layers of amorphous $Ti:Ta_2O_5$ and SiO_2

Deposited with ion beam sputtering (IBS)



The LIGO website. [Online image].
G.M. Harry et al. *Classical and Quantum Gravity*, 24(2):405, 2006

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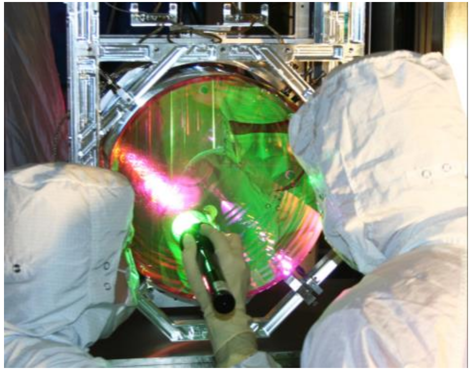

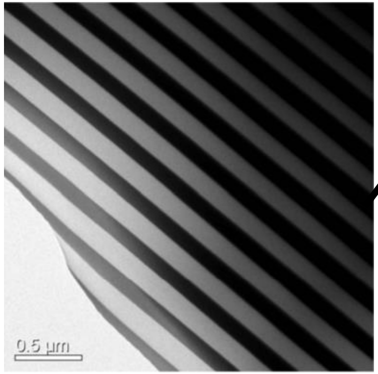

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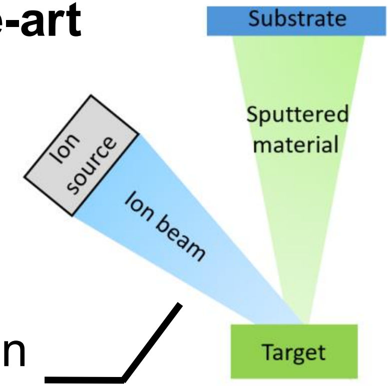

Optical and mechanical properties of amorphous materials depend on the stability of coating structure, which can change depending on the deposition process

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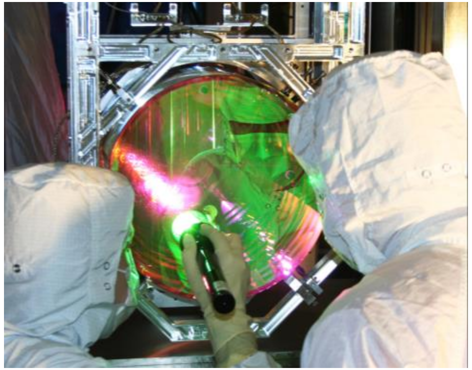

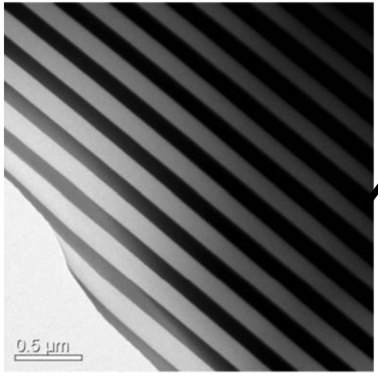

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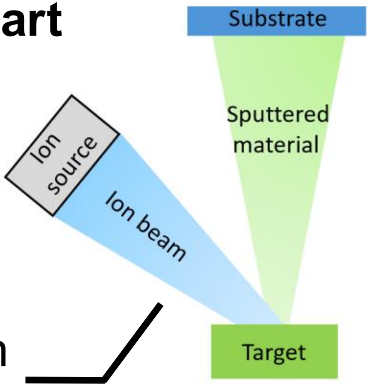

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✓ A different deposition technique might result in coatings with better performance

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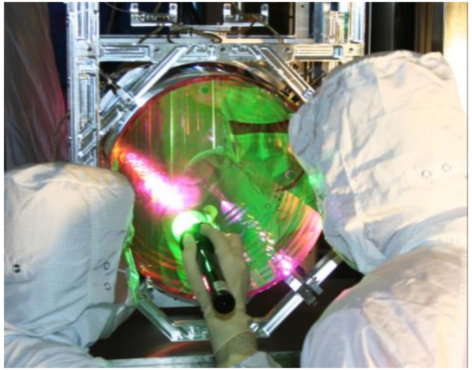

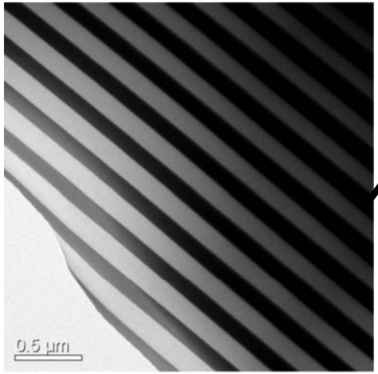

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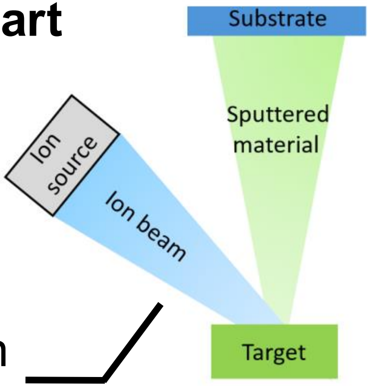

Optical and mechanical properties of amorphous materials depend on the stability of coating structure, which can change depending on the deposition process

✓ A different deposition technique might result in coatings with better performance

✓ A different deposition technique gives opportunities to get more insight in loss mechanisms

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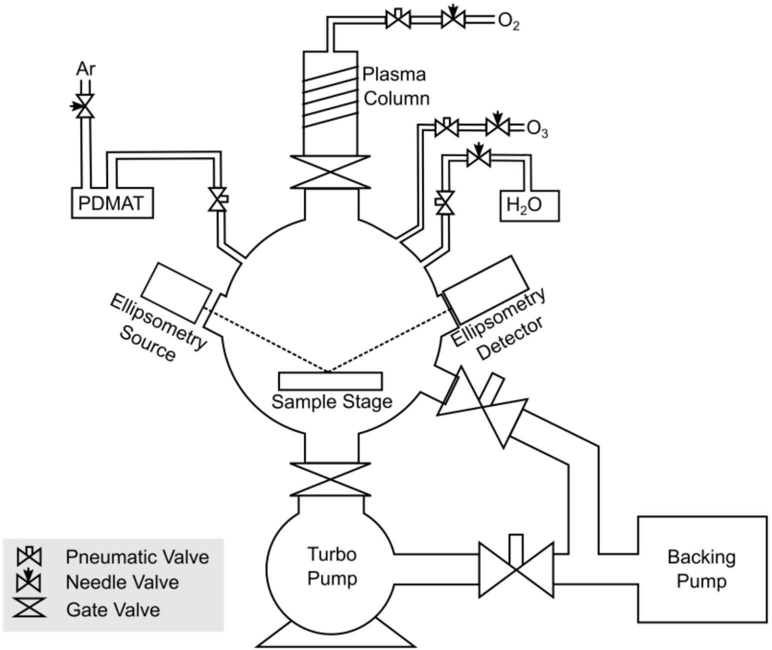
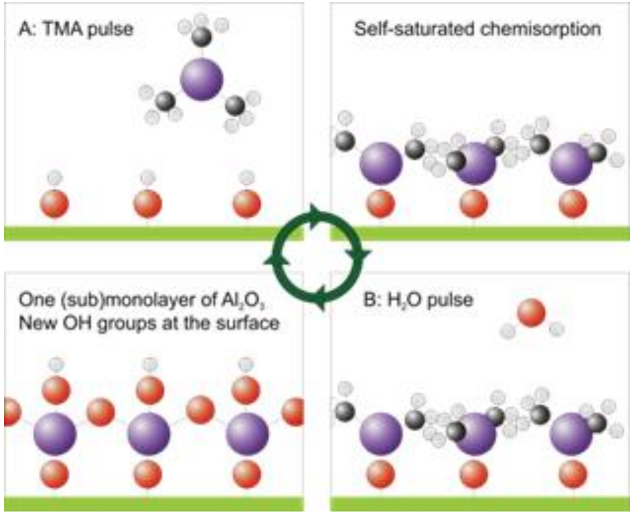
Atomic layer deposition (ALD)





Self-limiting reactions between substrate and precursor gases!

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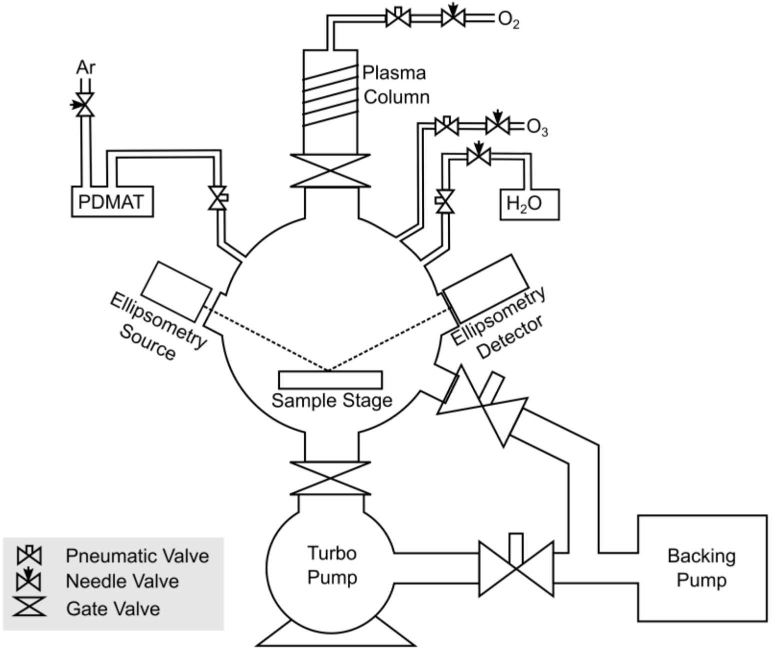

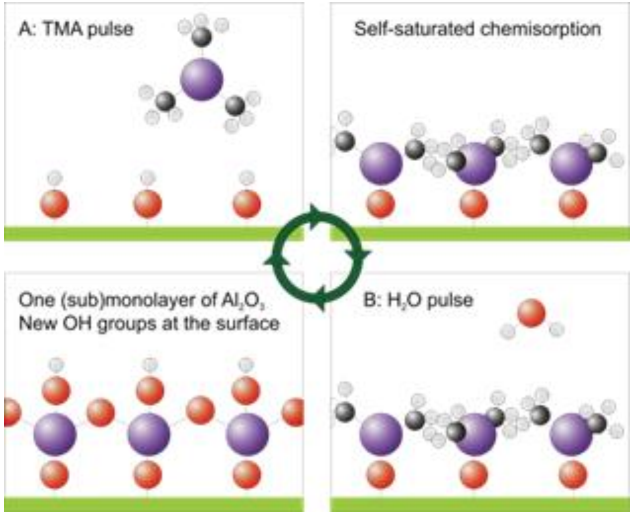

Self-limiting reactions between substrate and precursor gases!

✓ Atomic thickness control

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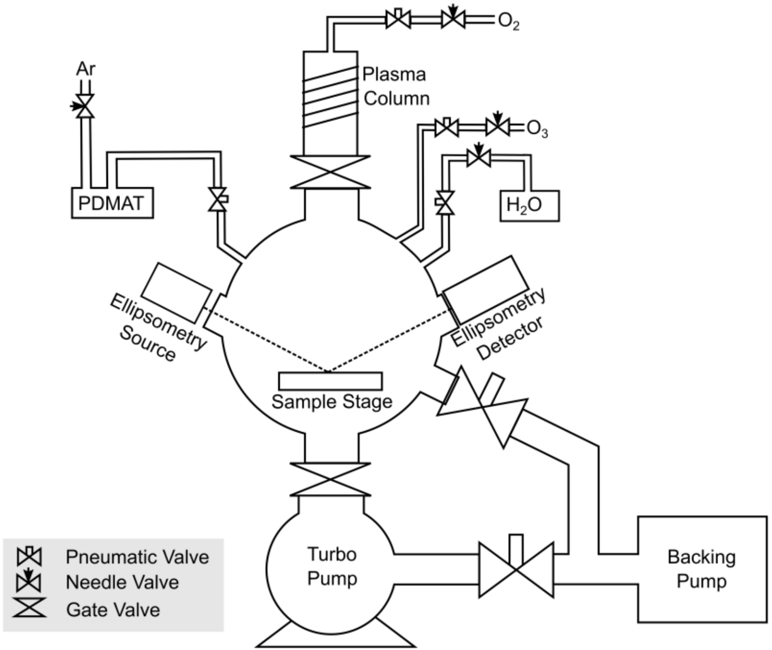

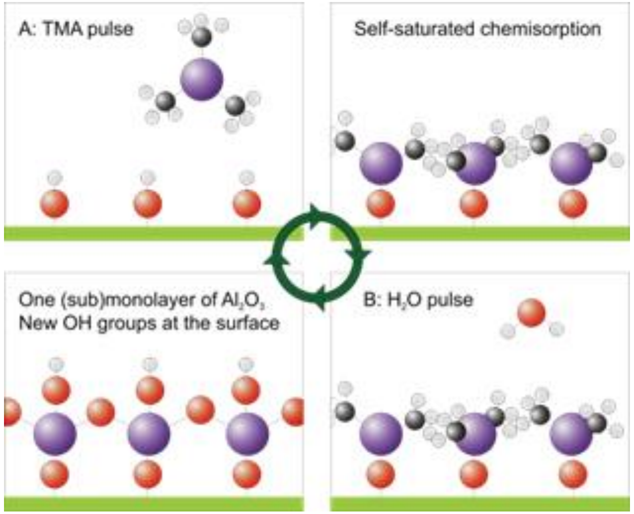

Self-limiting reactions between substrate and precursor gases!

- Atomic thickness control
- Superior uniformity

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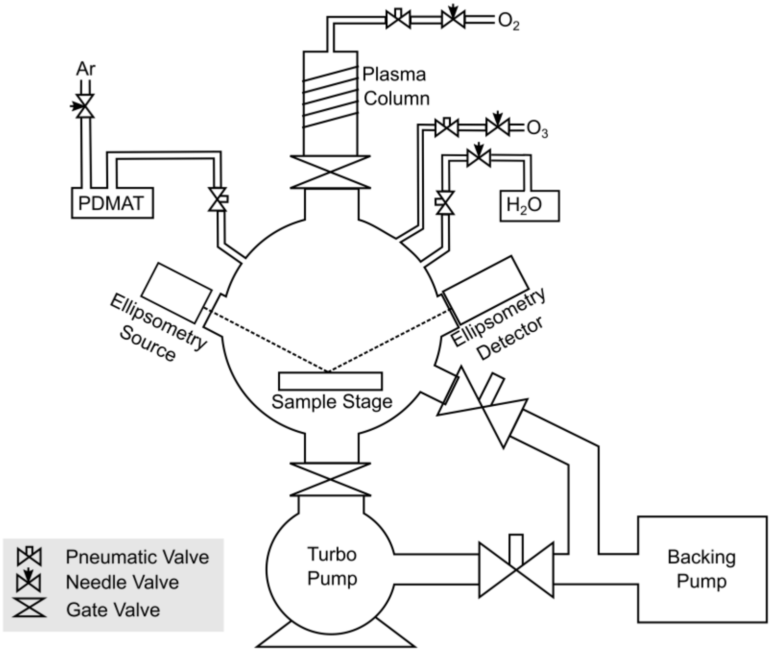

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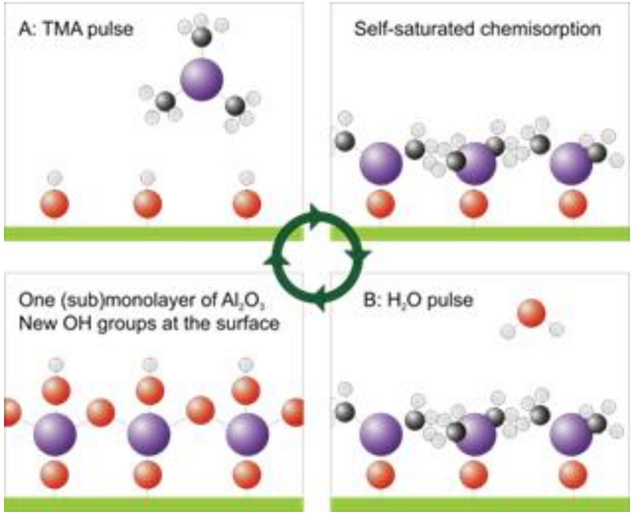

- Atomic thickness control
- Superior uniformity
- Easily scalable

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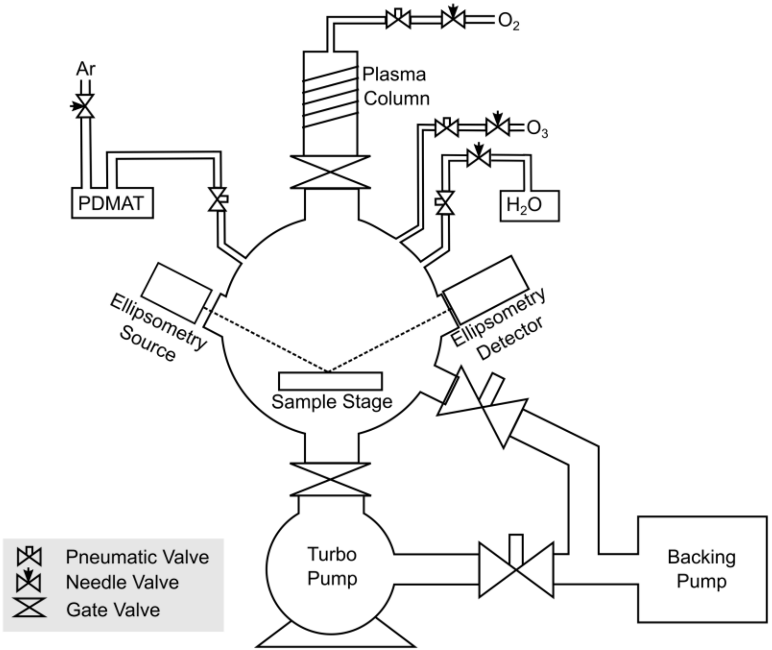

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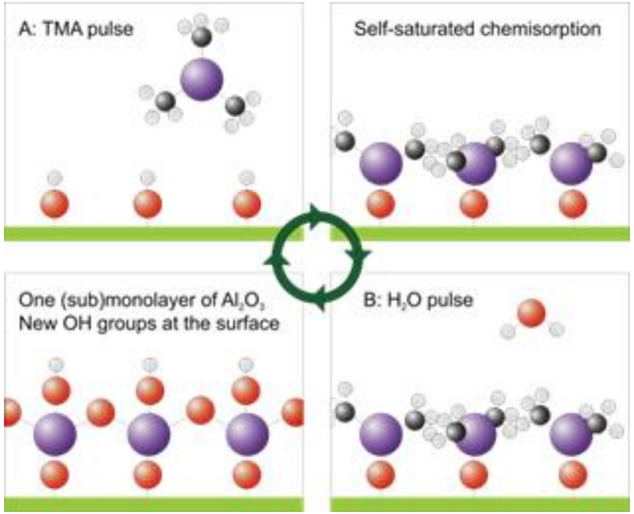

- Atomic thickness control
- Superior uniformity
- Easily scalable
- Wide variety of materials

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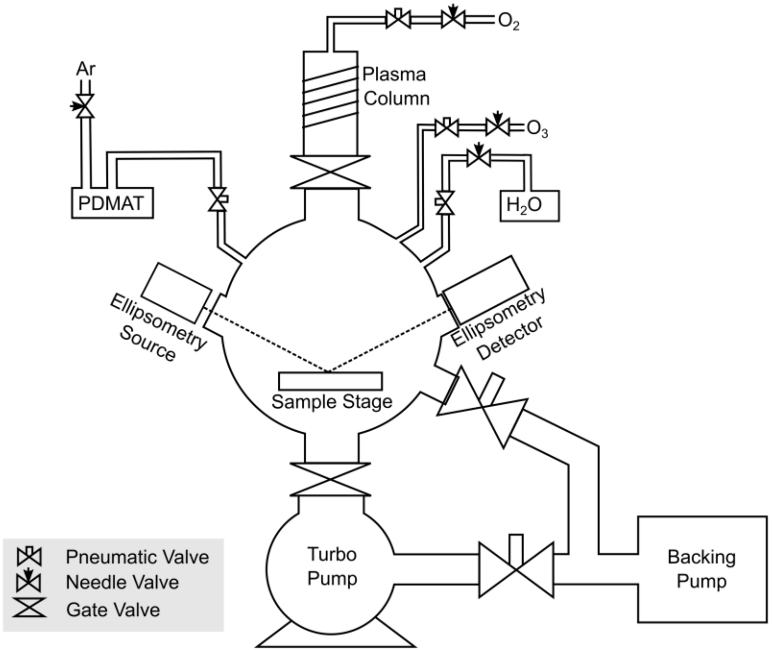

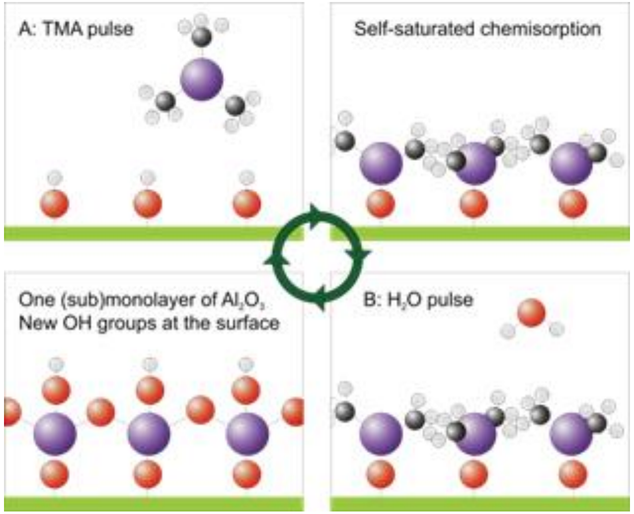

Self-limiting reactions between substrate and precursor gases!

- ✓ Atomic thickness control
- ✓ Superior uniformity
- ✓ Easily scalable
- ✓ Wide variety of materials
- ✗ Slow

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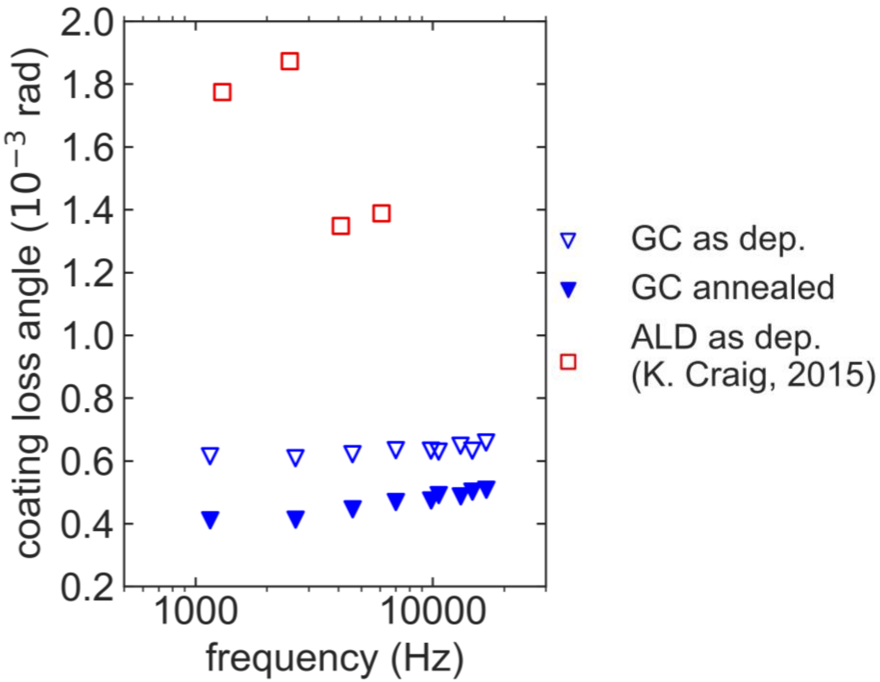
ALD Ta_2O_5

An earlier study found a very high loss of ALD tantala

However, the process details were not given, and ALD has a lot of parameters that can be optimised



M. Granata et al. *Class. Quantum Grav.* 37 095004, 2020
K. Craig. [PhD thesis]. University of Glasgow, 2015

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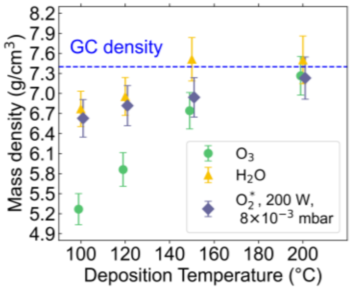
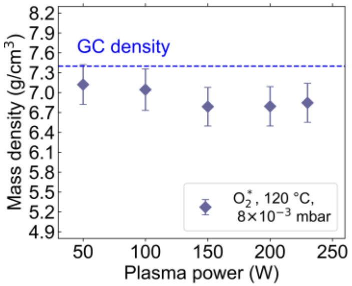
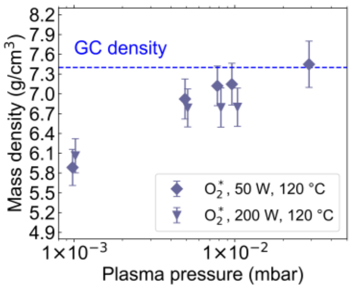
Process optimisation

Process optimisation







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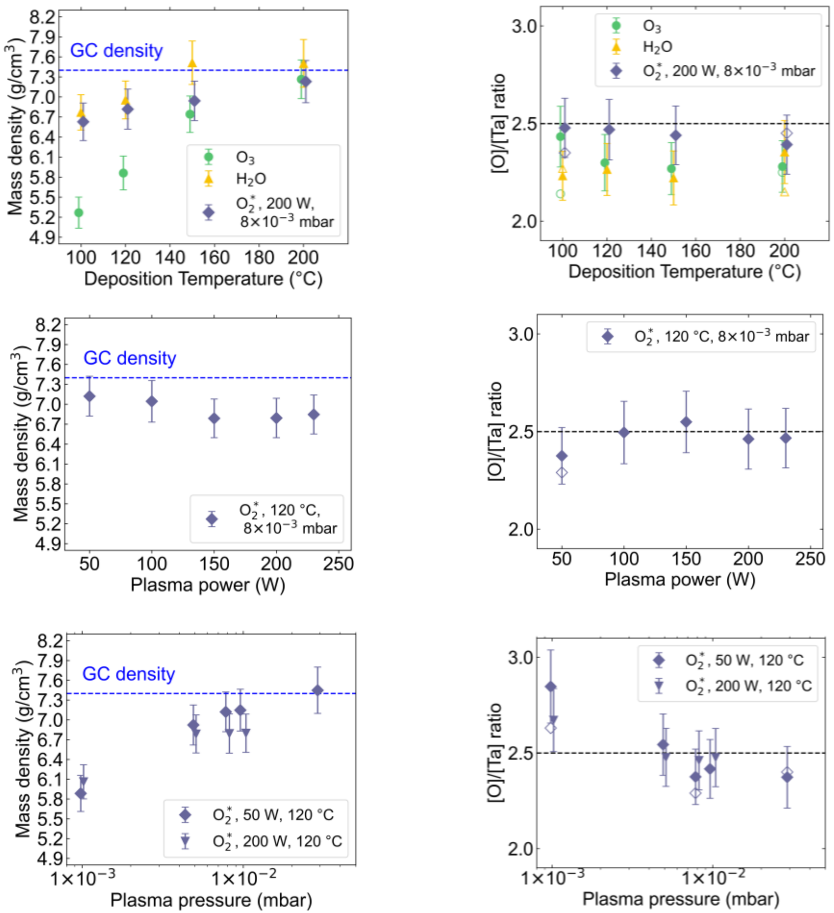

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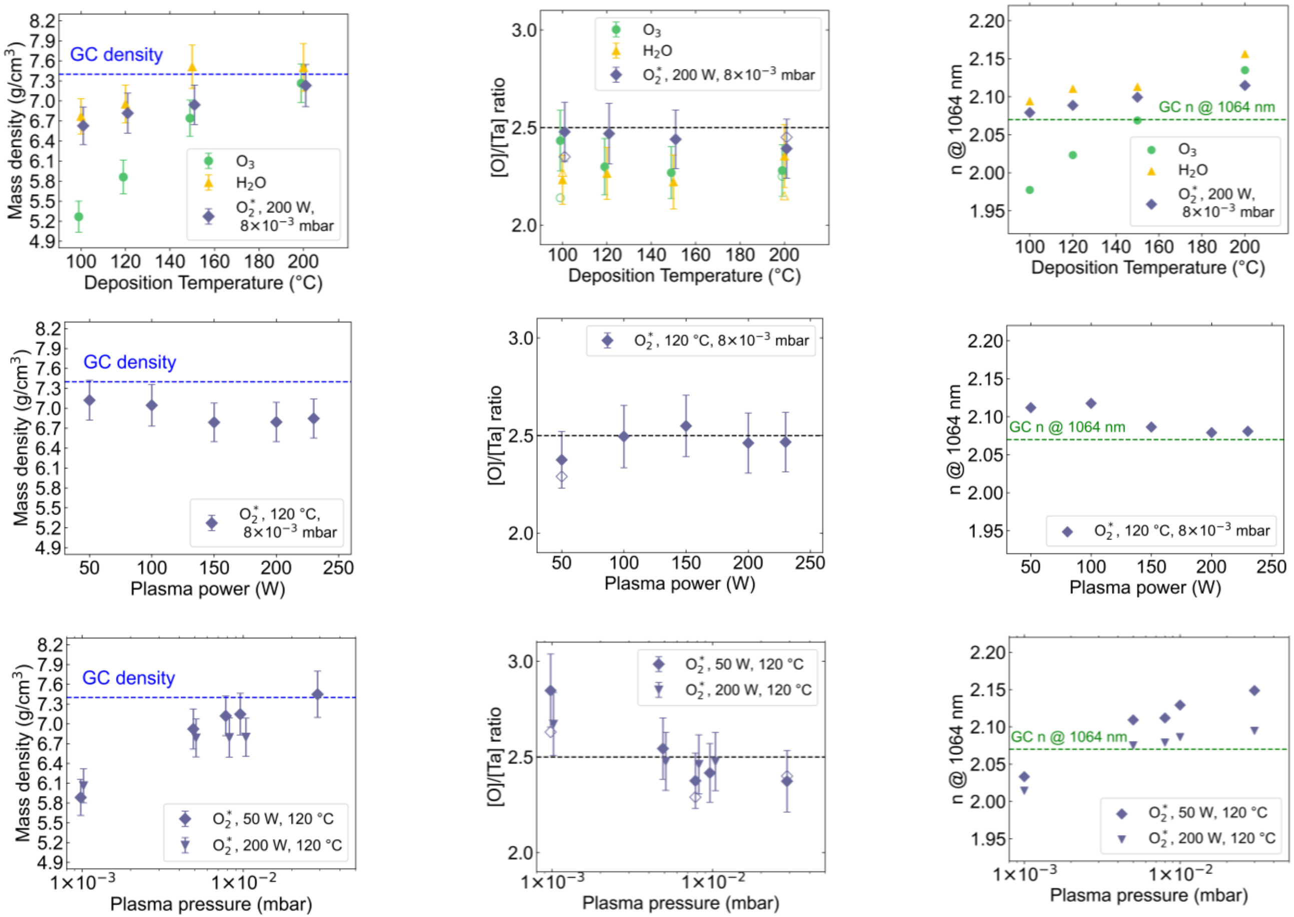

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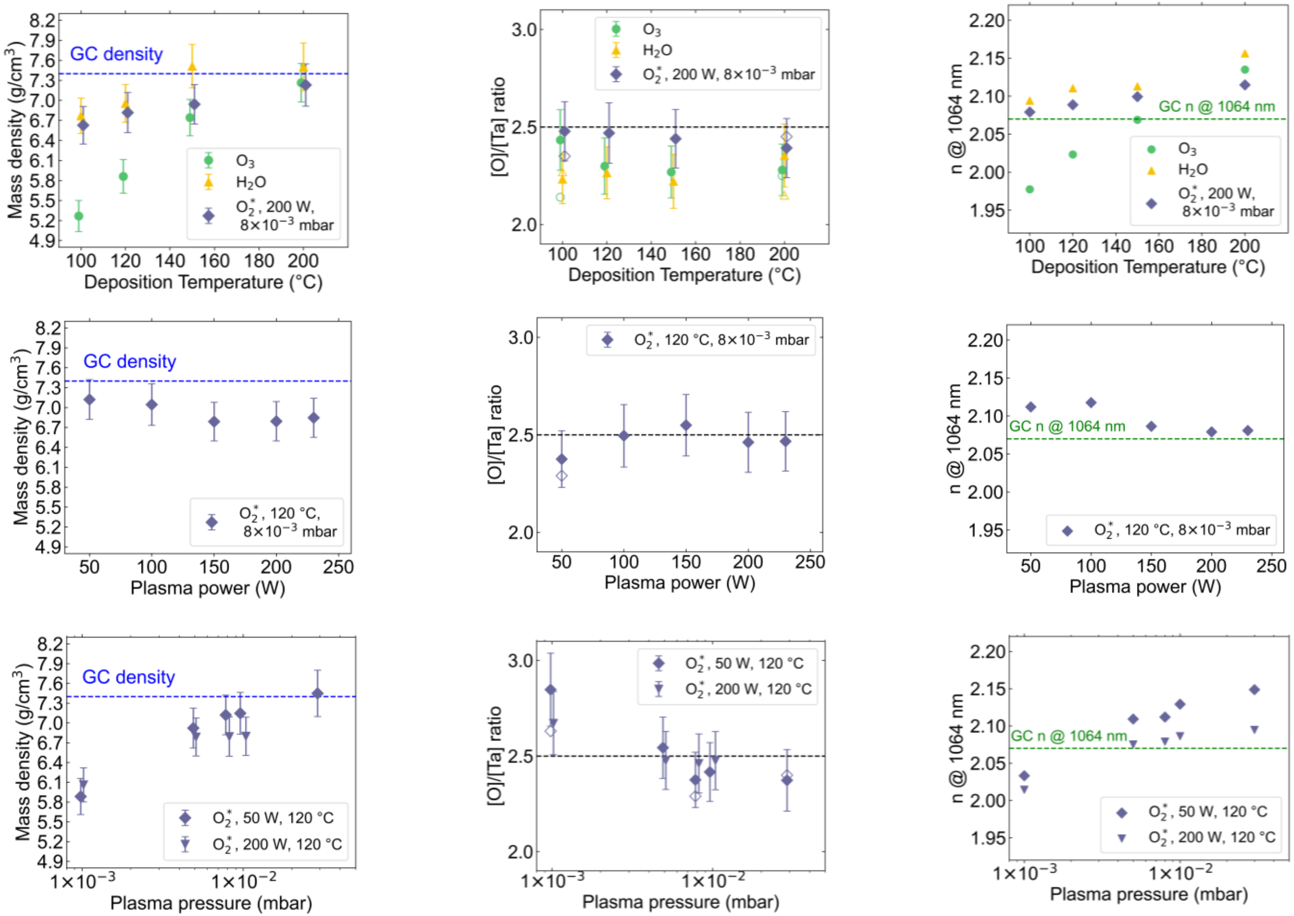
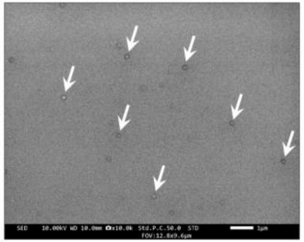
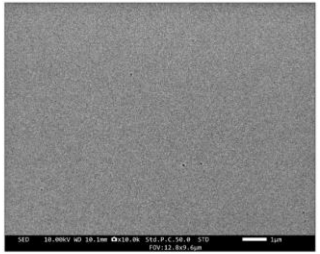


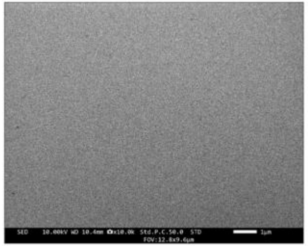
O_2*, 100 °C,
200 W, 8e-3 mbar



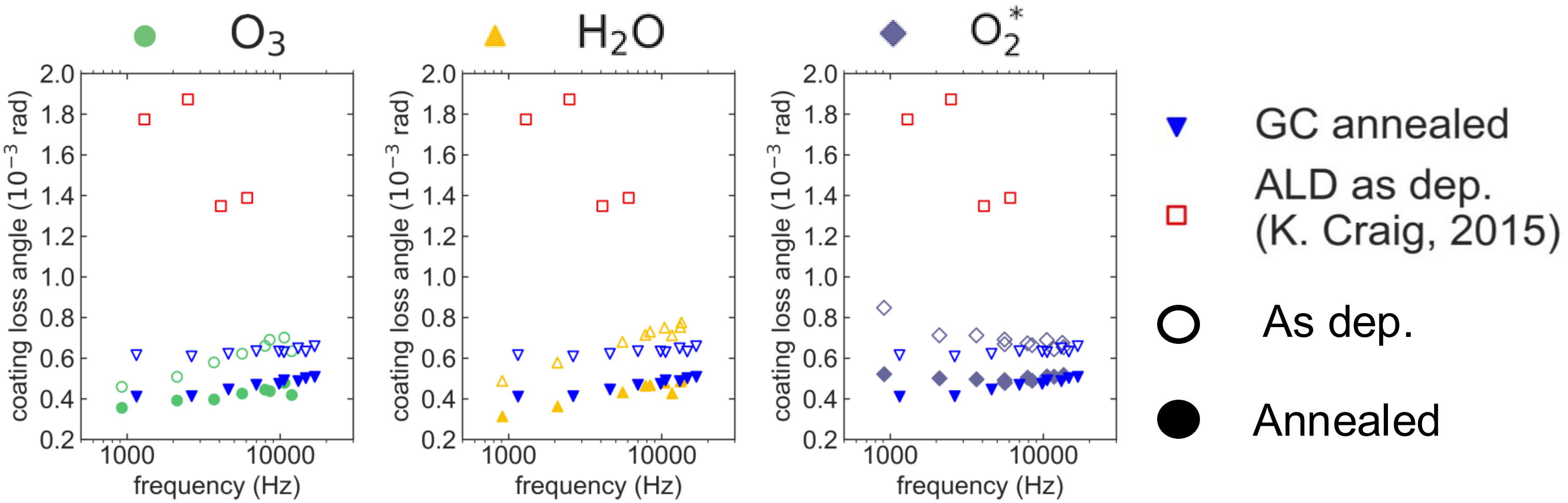
O_2*, 200 °C,
200 W, 8e-3 mbar



O_2*, 120 °C,
50 W, 1e-2 mbar



Mechanical loss and optical absorption



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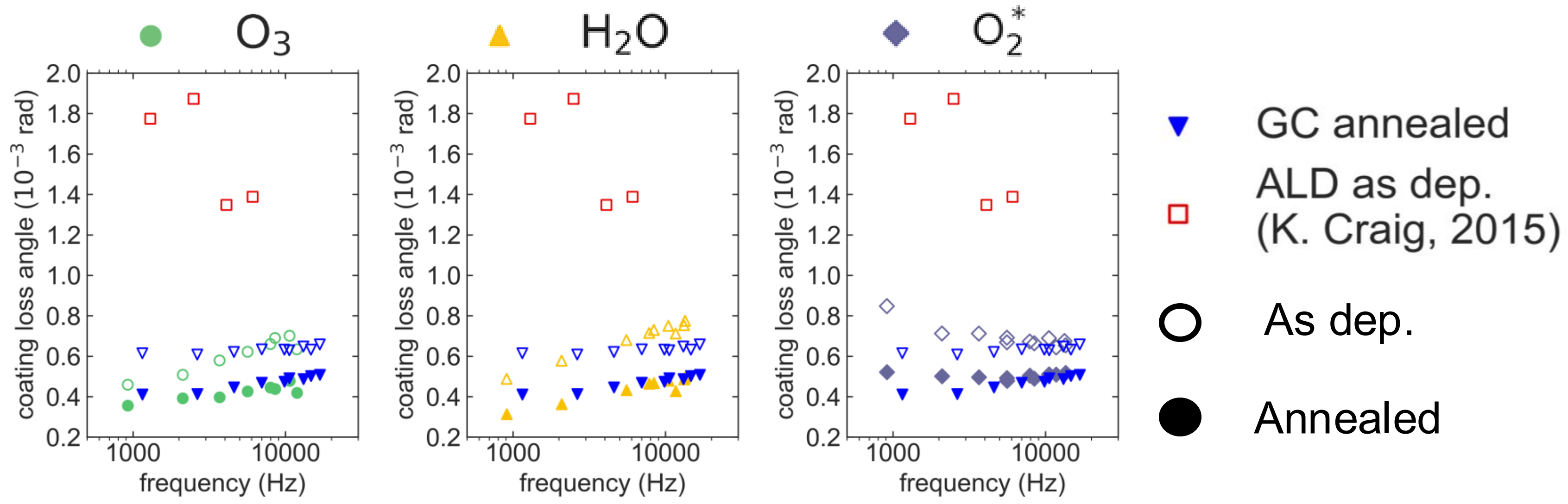
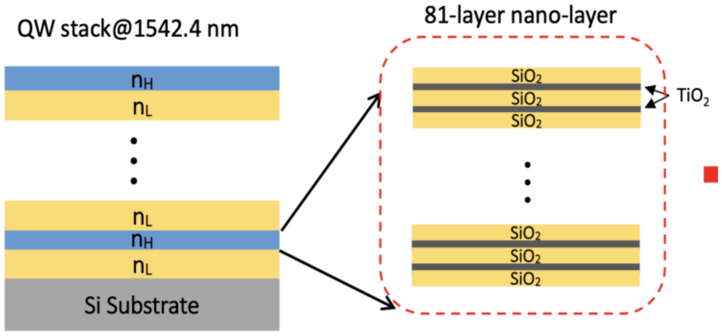


Co-reactant	State	Thickness (nm)	Abs. @ 1550 nm (ppm)	k @ 1550 nm	n @ 1550 nm	n @ 1064 nm
O_3	as dep.	289	15.1	6.4×10^{-6}	2.02	2.04
	annealed	305	60.0	2.4×10^{-5}	2.04	2.05
H_2O	as dep.	381	68.7	2.2×10^{-5}	2.09	2.10
	annealed	375	52.7	1.7×10^{-5}	2.09	2.10
O_2^*	as dep.	300	6.60	2.7×10^{-6}	2.08	2.09
	annealed	309	2.75	1.1×10^{-6}	2.08	2.09

M. Granata et al. *Class. Quantum Grav.* 37 095004, 2020

Future perspective: atomically layered laminates

Engineering of refractive index and crystallisation temperature



	n	κ	*d* (nm)
TiO_2	2.27	1.1×10^{-5}	1.8
SiO_2	1.44	0	3.6

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Ling-Chi Kuo et al, Opt. Lett. 44, 247-250 (2019)

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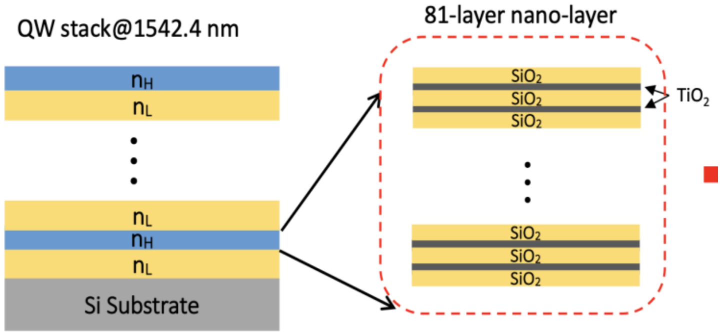

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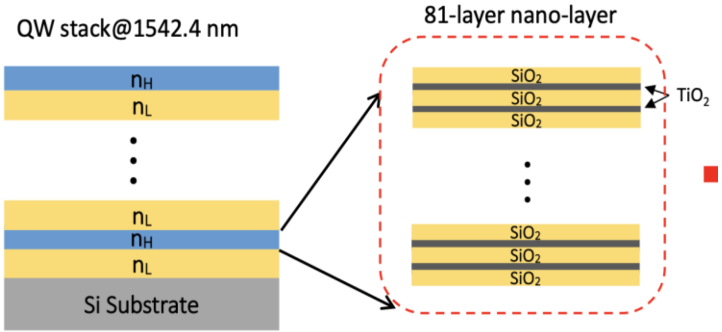

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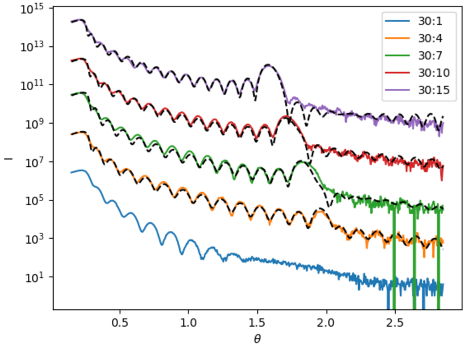

	TiO2 (nm/layer)	SiO2 (nm/layer)
14(30+1)	?	?
14(30+4)	1.9	0.2
14(30+7)	2.0	0.3
14(30+10)	2.1	0.4
14(30+15)	2.0	0.6

ALD: down to 0.1 nm

Very controllable and reproducible

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VIR-0732A-21

Ling-Chi Kuo et al, Opt. Lett. 44, 247-250 (2019)

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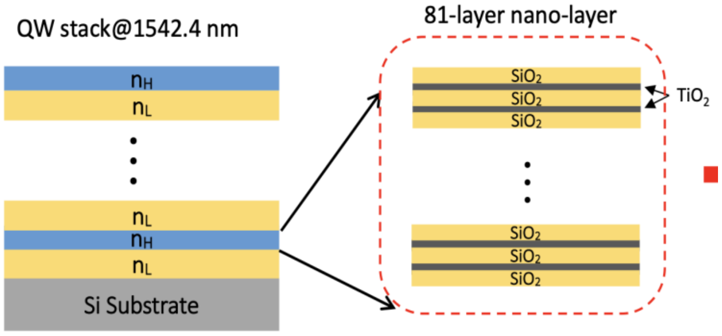

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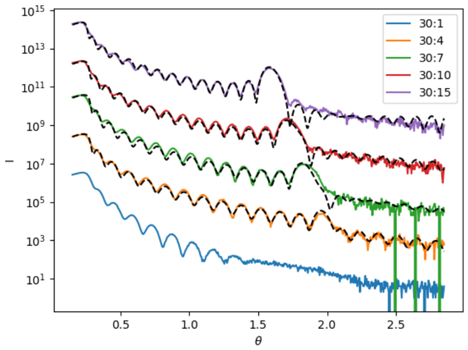

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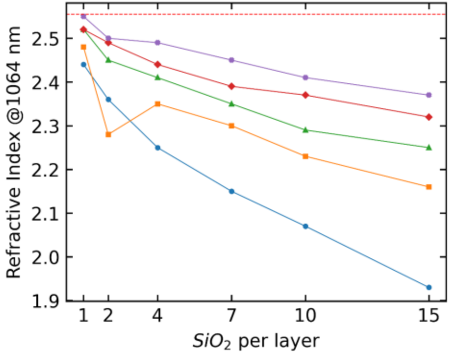

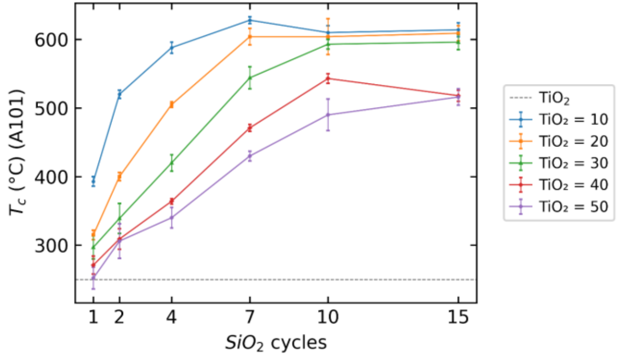

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X-ray characterisation of mirror coatings

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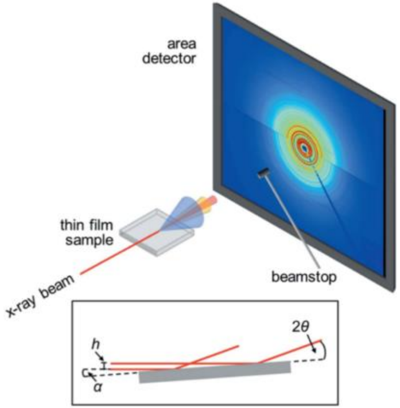
Structural characterisation of amorphous layers by total x-ray scattering experiments



Ann-Christine Dippel et al. (DESY) - IUCrJ, no. 6.2, 2019

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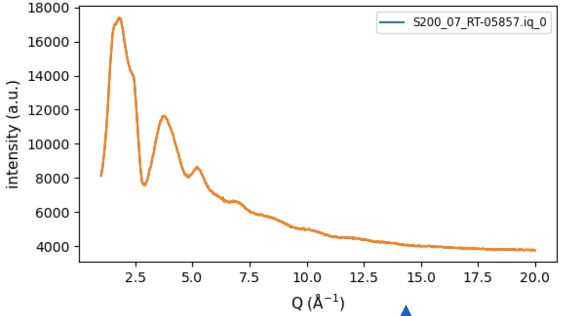

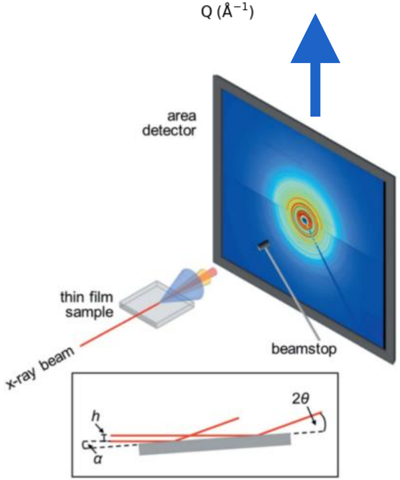

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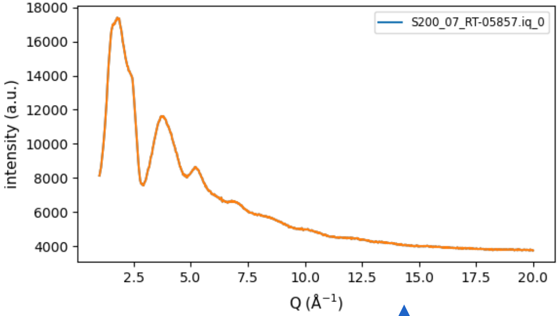
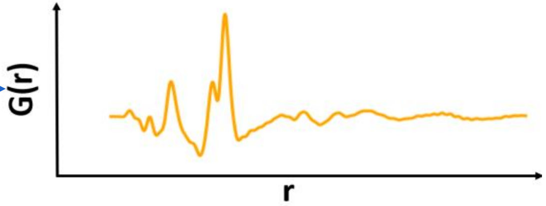
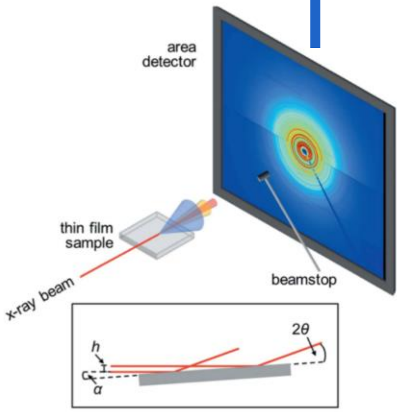


Pair distribution function (PDF)





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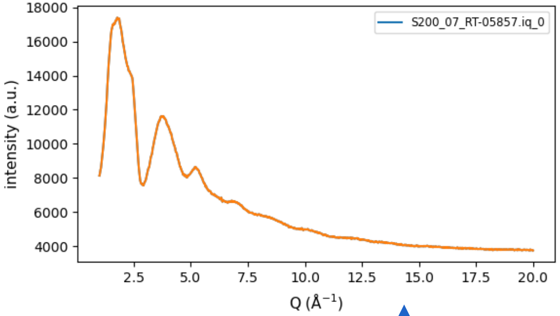

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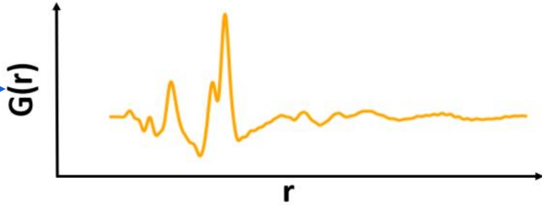

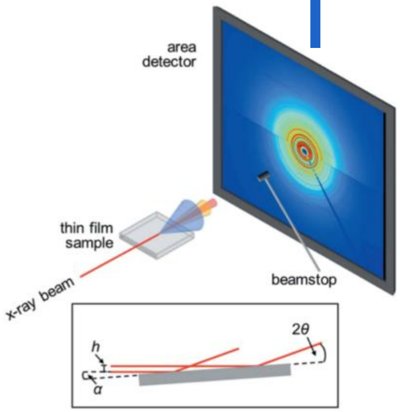

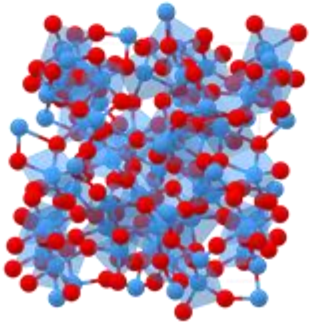

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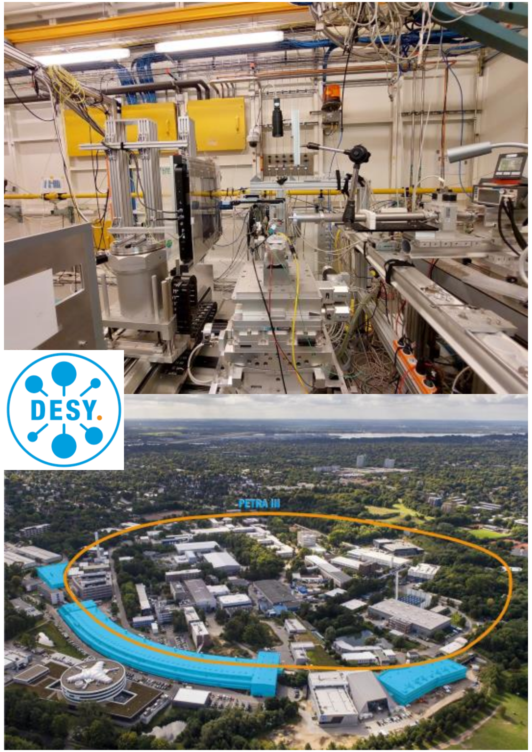
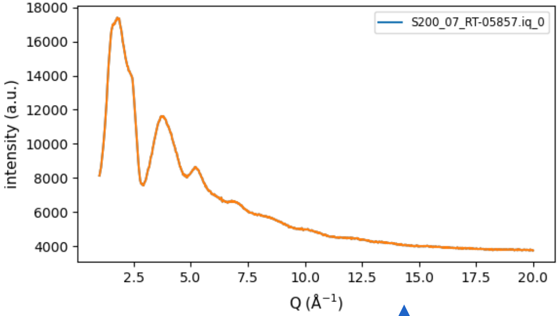
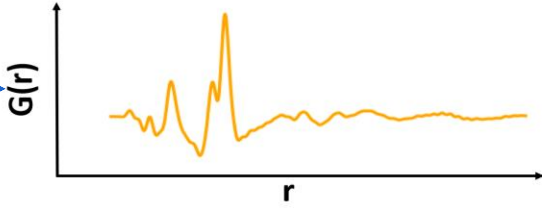
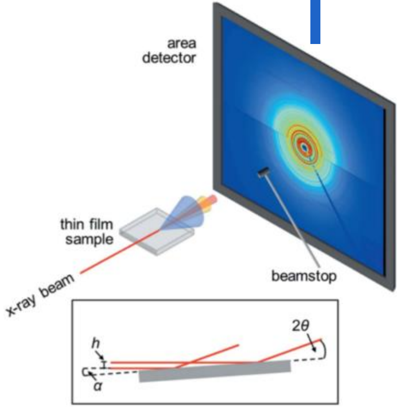
Structural characterisation of amorphous layers by total x-ray scattering experiments

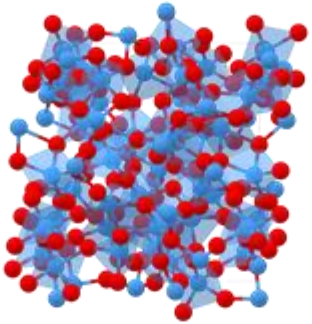




Pair distribution function (PDF)







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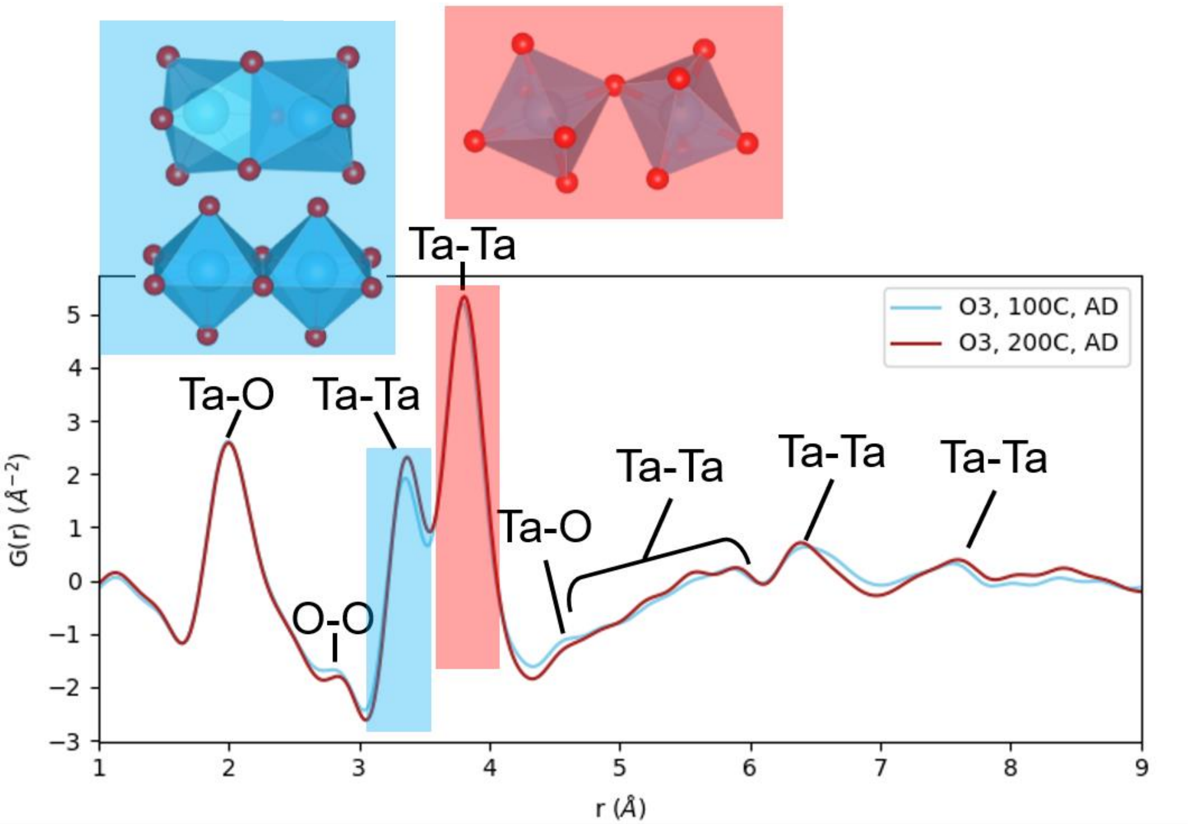
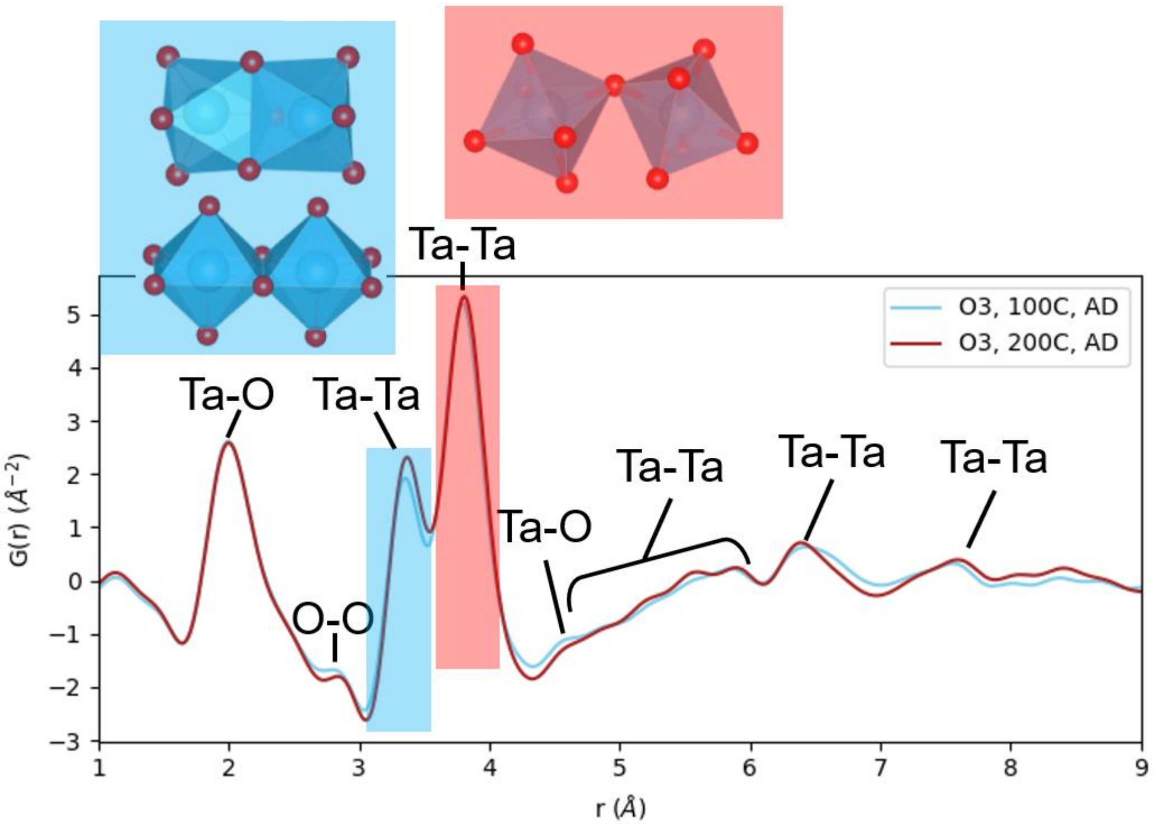
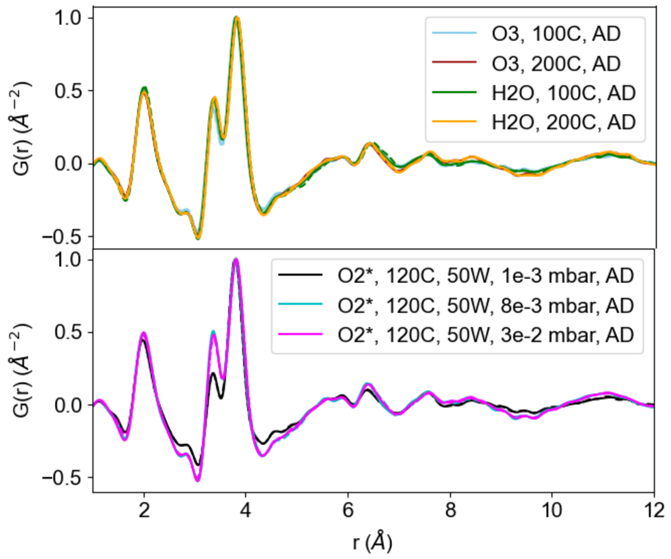
PDF of Ta_2O_5 coating measured by GI-PDF @ DESY

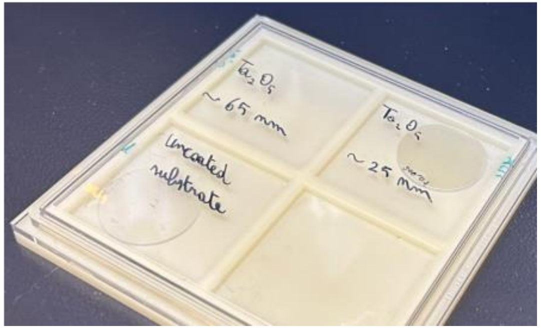


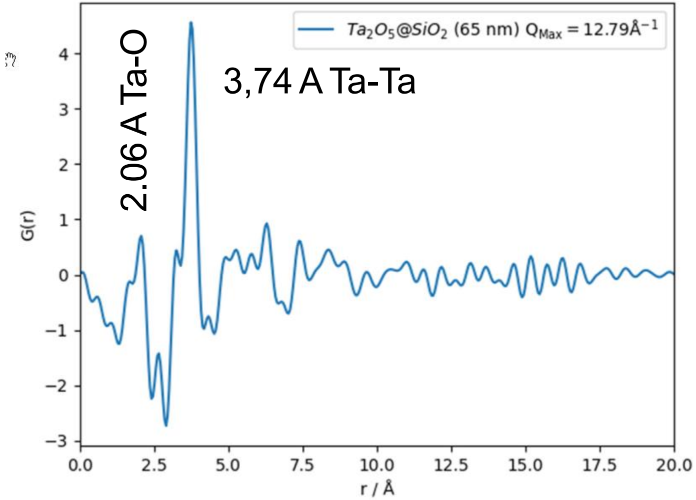
PDF of Ta_2O_5 coating measured by GI-PDF @ DESY



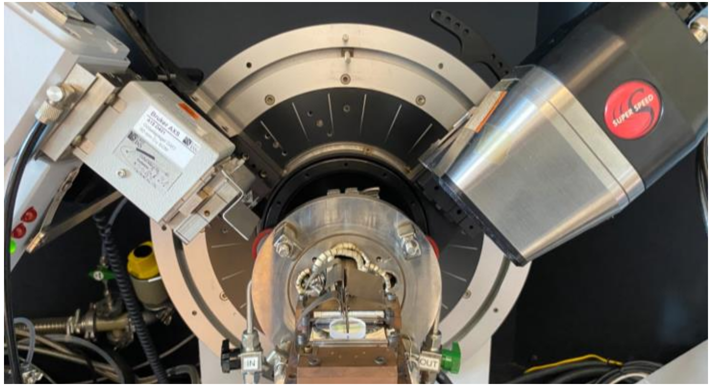


IRI proposal: lab tool total x-ray scattering @ UGent



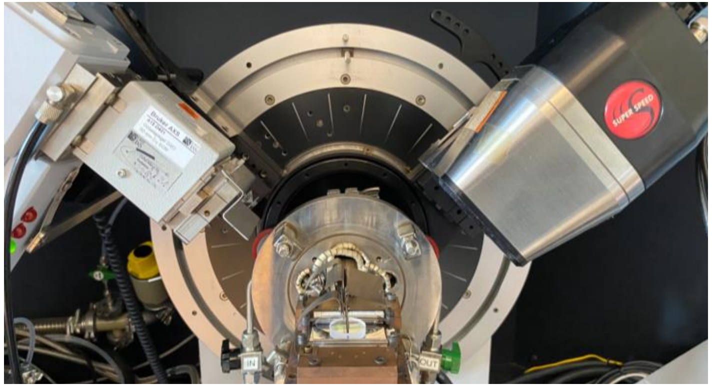


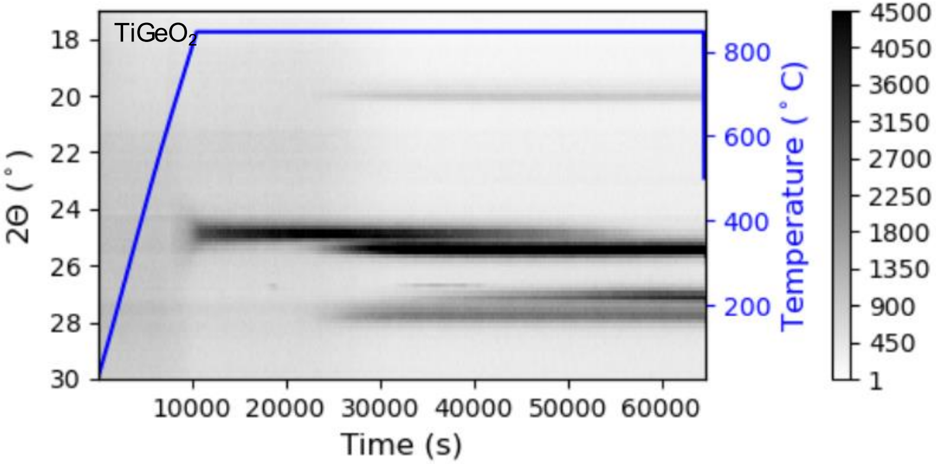
X-ray diffraction to optimise post-deposition anneal $TiGeO_2$ and $TiSiO_2$ coatings for VIRGO

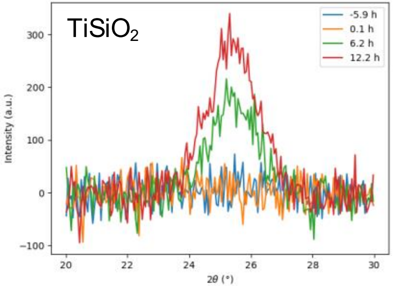


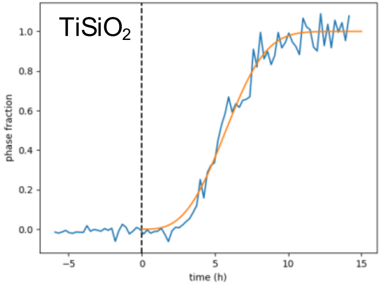
Coatings deposited at LMA and Glasgow, crystallisation study in collaboration with Marco Bazzan, Padova.

X-ray diffraction to optimise post-deposition anneal $TiGeO_2$ and $TiSiO_2$ coatings for VIRGO



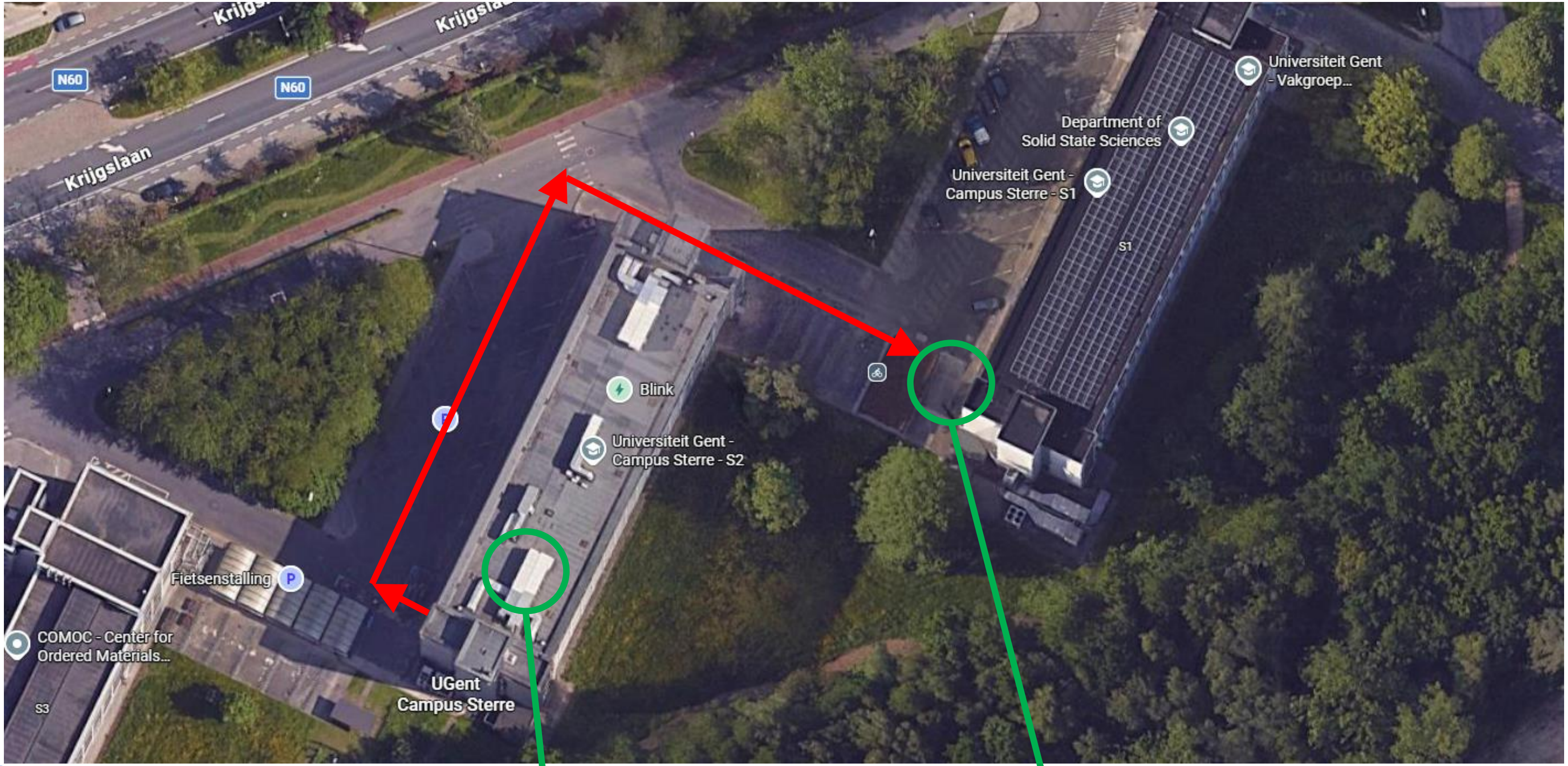






Coatings deposited at LMA and Glasgow, crystallisation study in collaboration with Marco Bazzan, Padova.

CoCooN lab tour during lunch break



You are here

Start of lab tour

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