Possible Material-Saving Approach of Sputtering Techniques for Radiopharmaceutical Target Production

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WTTC18

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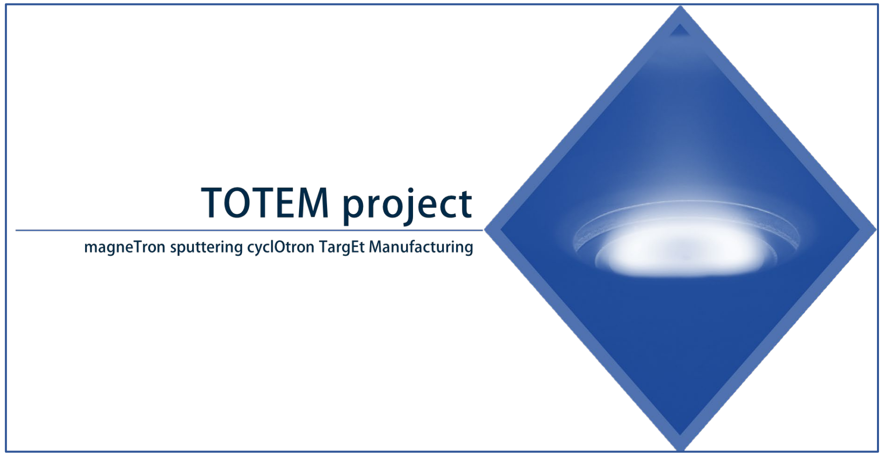
Work Goal

To evaluate the main magnetron sputtering technique issues and to found a possible solution to use this technique <u>for solid target production</u>



This research was funded by CSN5 of the INFN, Italy for 2018–2022, in the framework of METRICS project. PI: J. Esposito and by INTEFF program at INFN funded by MISE, Italy – in the framework of TOTEM project PI: S.Cisternino.

Outline

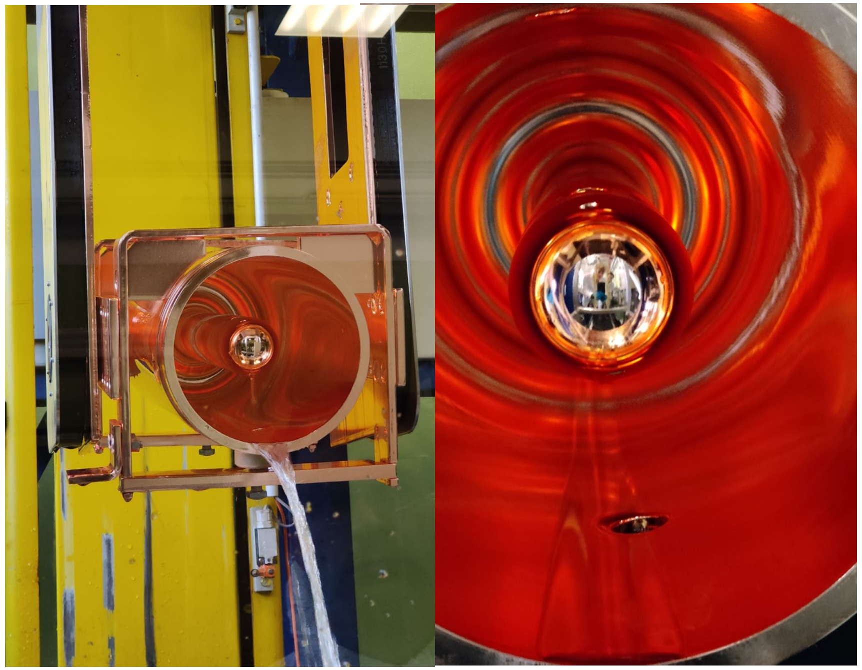
1 Introduction to Sputtering techniques

2 Results on magnetron sputtering optimization

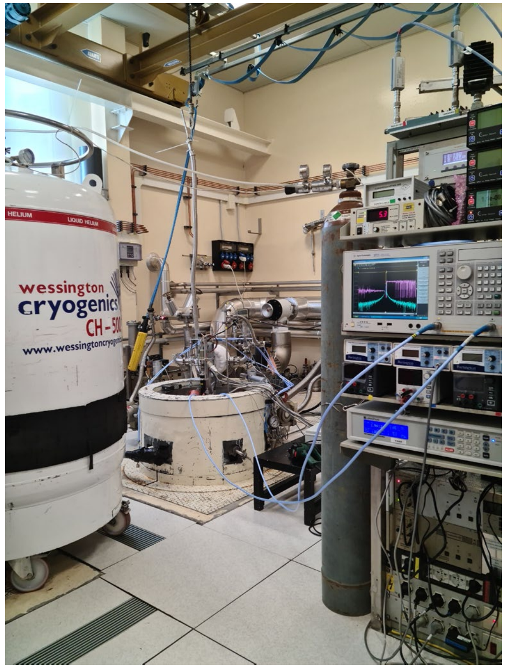
3 Results on nat-ZnO targets realization

1 Surface Technologies and Superconductivity Service

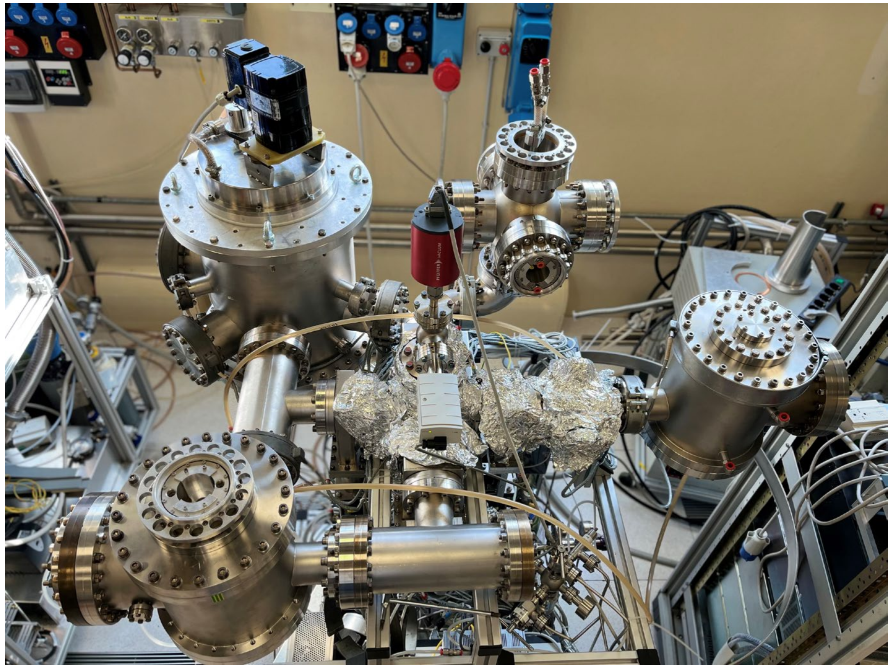
Chemistry laboratory



Cryo laboratory



Sputtering laboratory



Advanced surface treatments for Cu and Nb accelerating cavities

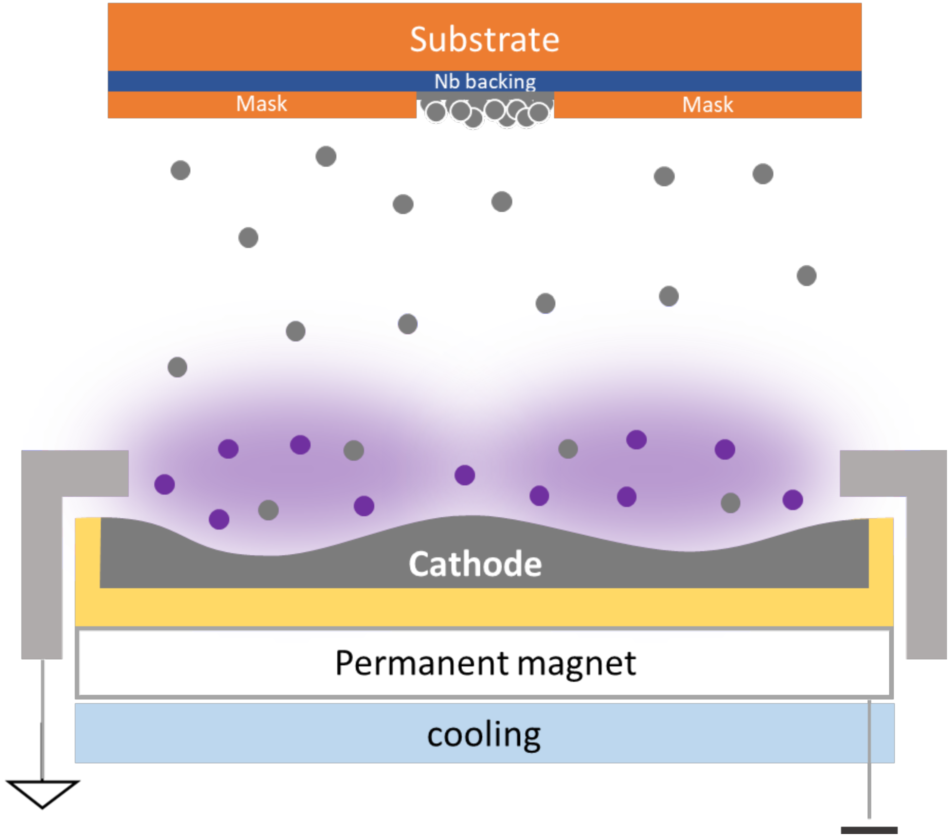
Superconductive Nb depositions

Cryogenic characterization

- Various PVD machines for industrial and scientific interests
- Deposition of metals and ceramic compounds on different substrates

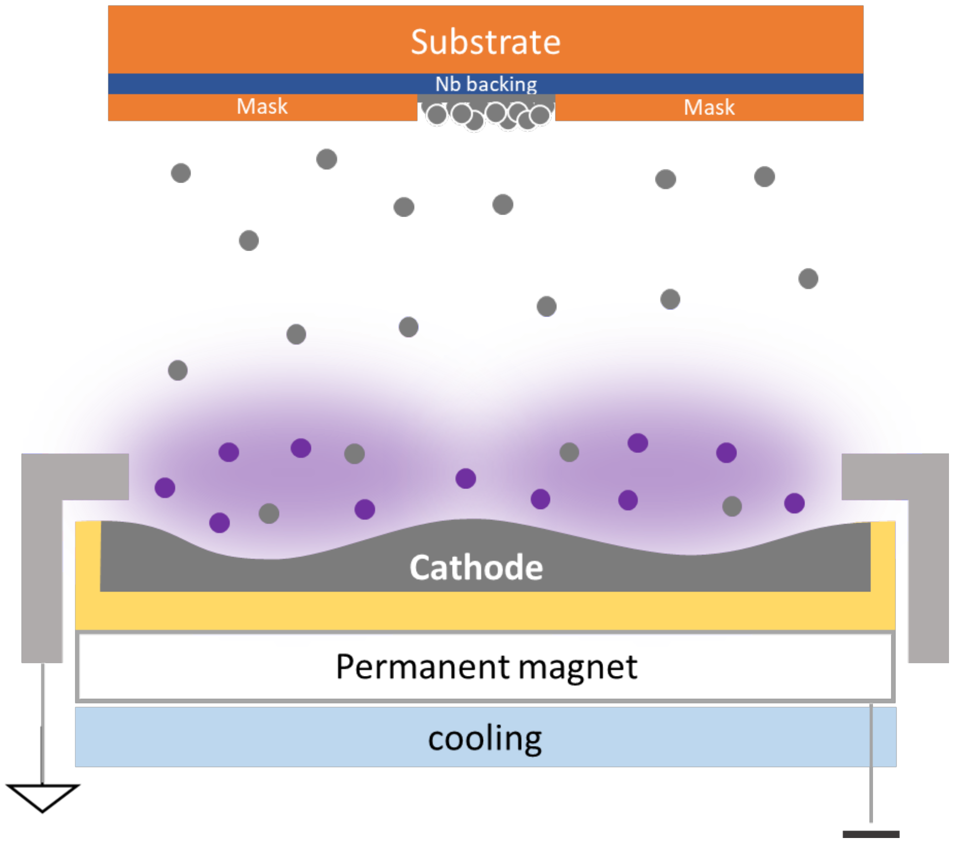
1 Magnetron sputtering

Planar magnetron sputtering

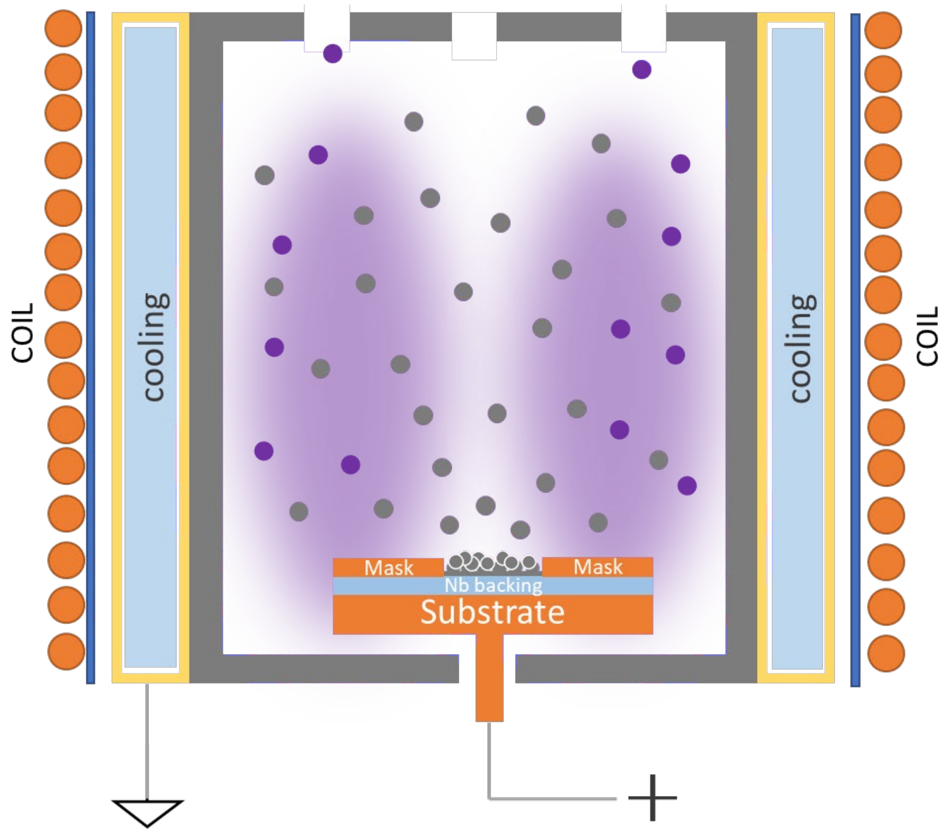


1 Magnetron sputtering

Planar magnetron sputtering



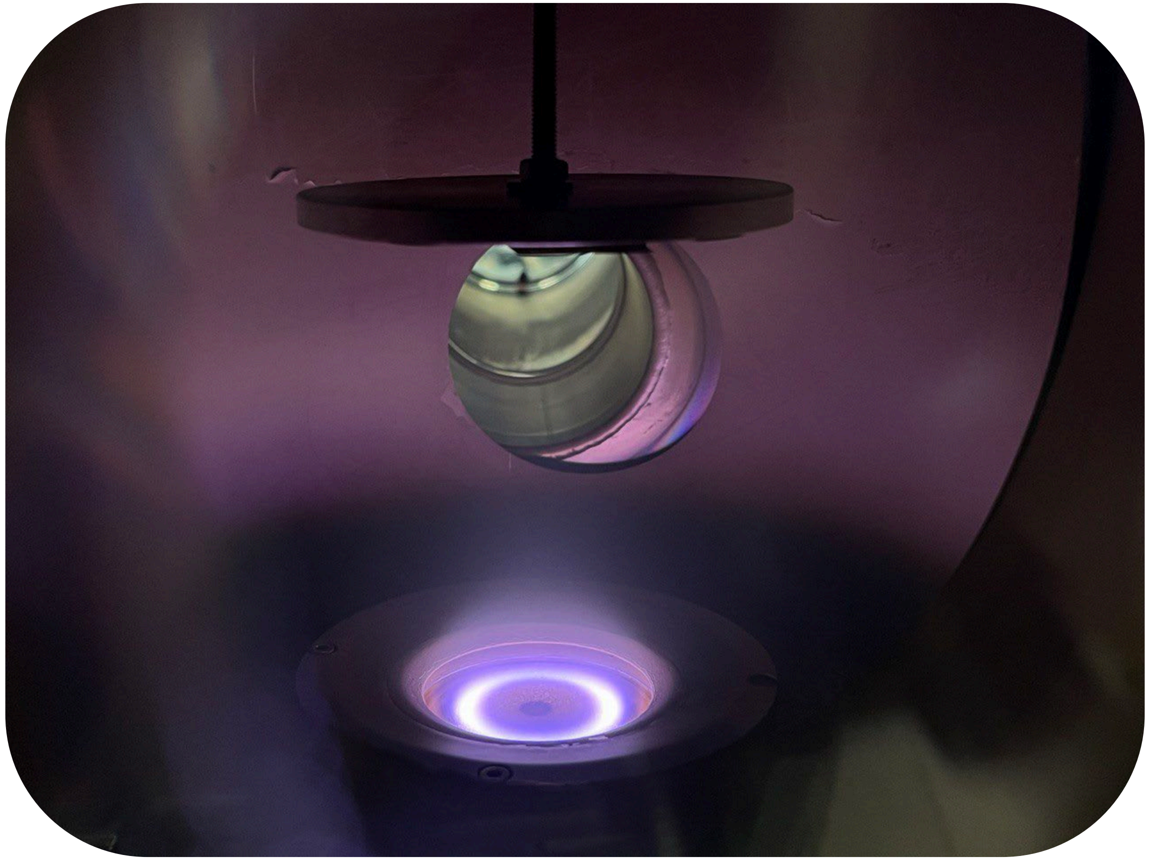
Idea of inverted magnetron sputtering



1 Magnetron sputtering - characteristics

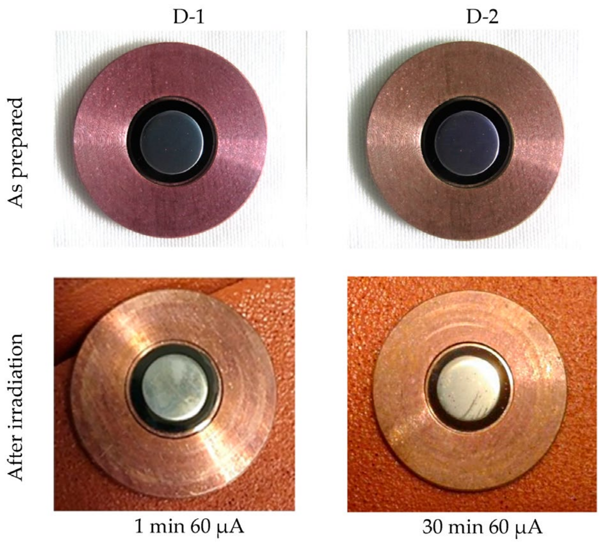
- ✓ Precise thickness control
- ✓ High adherence
- ✓ Densification of the deposition

- ➢ Material sputtered everywhere in the vacuum chamber
- ➢ Material losses – 80%



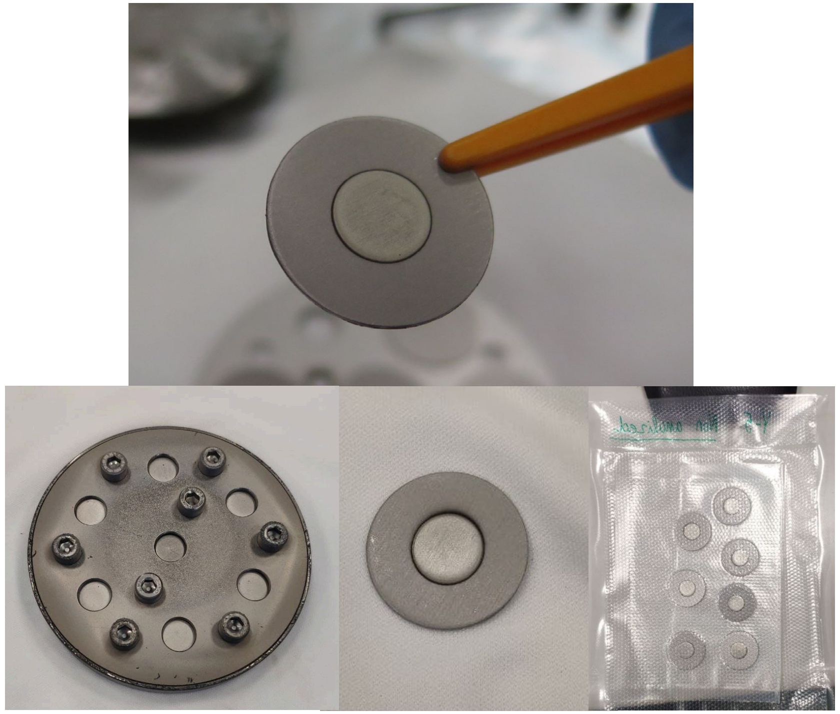
1 Magnetron sputtering for target production

nat-Mo targets preparation



[Patent n. WO 2019/053570]
[Skliarova et al., Molecules 2021]

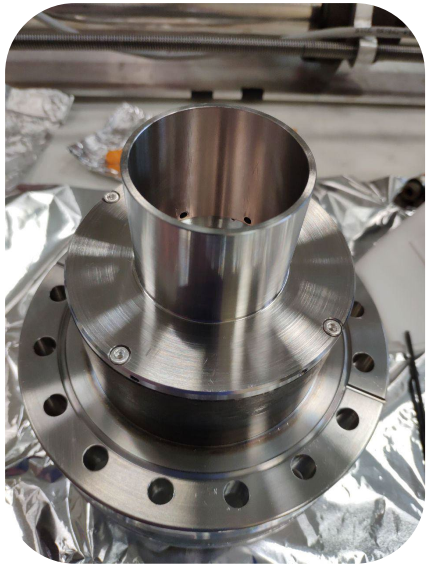
nat-Y target preparation

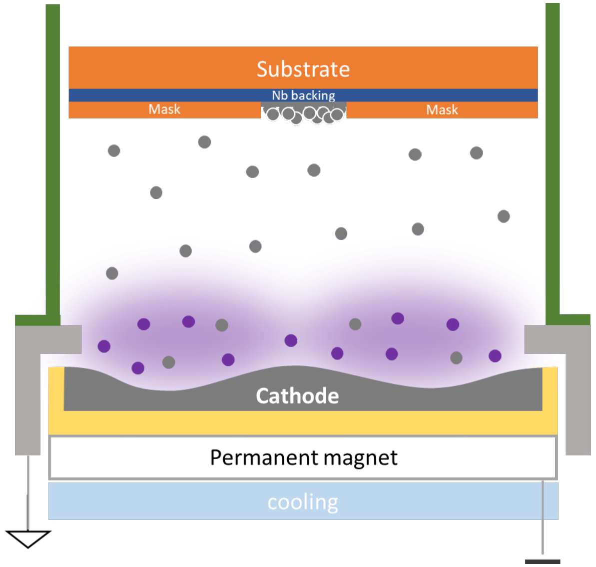


- 7 targets simultaneous depositions
- Thickness range – 150-200 μm

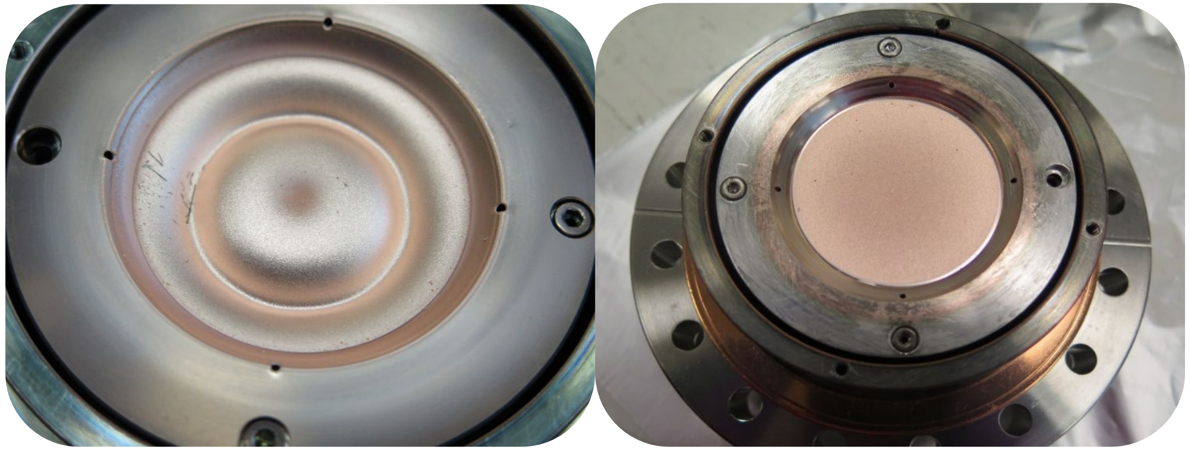
2 Possible material-saving approach

2 inch planar magnetron evaluation





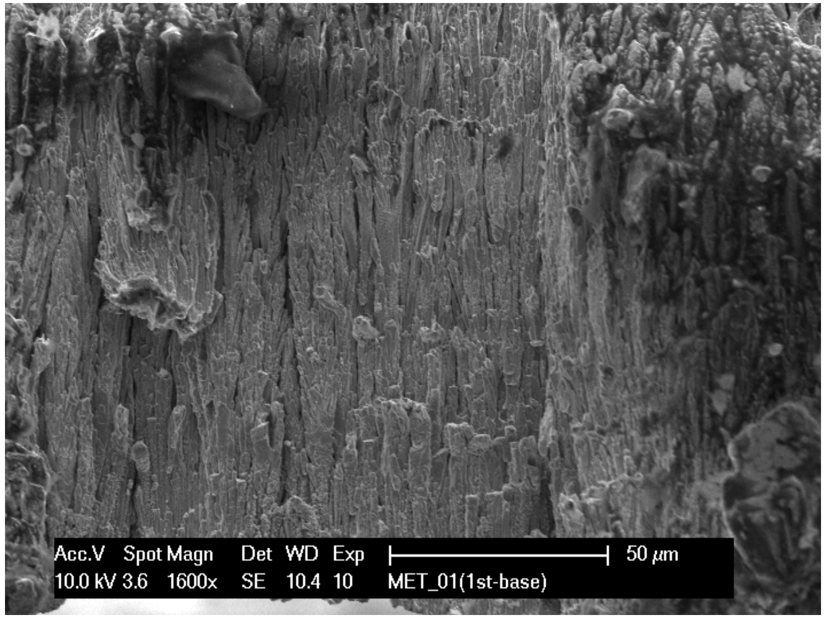
Recovering shield

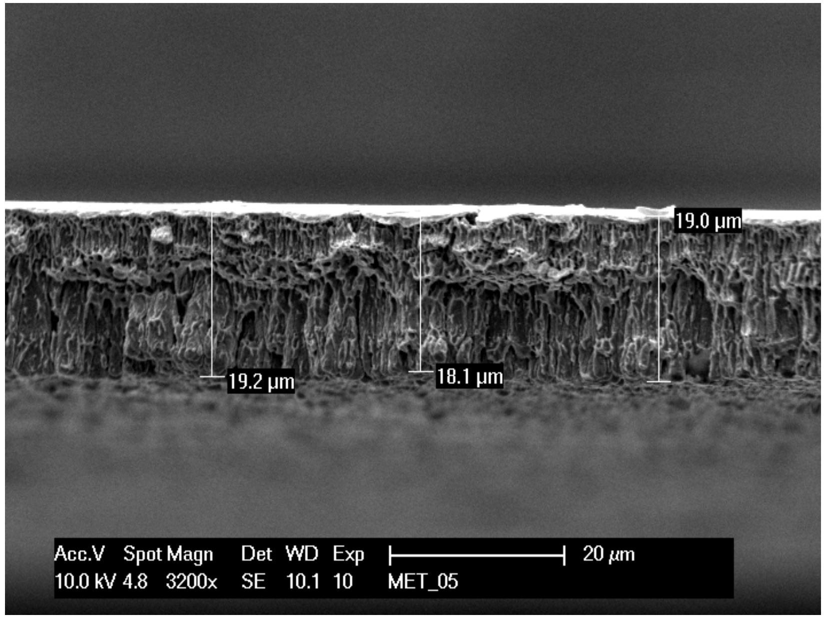


Magnetron and diode sputtering techniques

2 Possible material-saving approach

Material results	Magnetron,%	Diode, %
On the substrate	38,9±0,003	21,6±0,035
On the shield	56,3±0,005	71,6±0,113
Losses	4,8±0,008	6,8±0,148



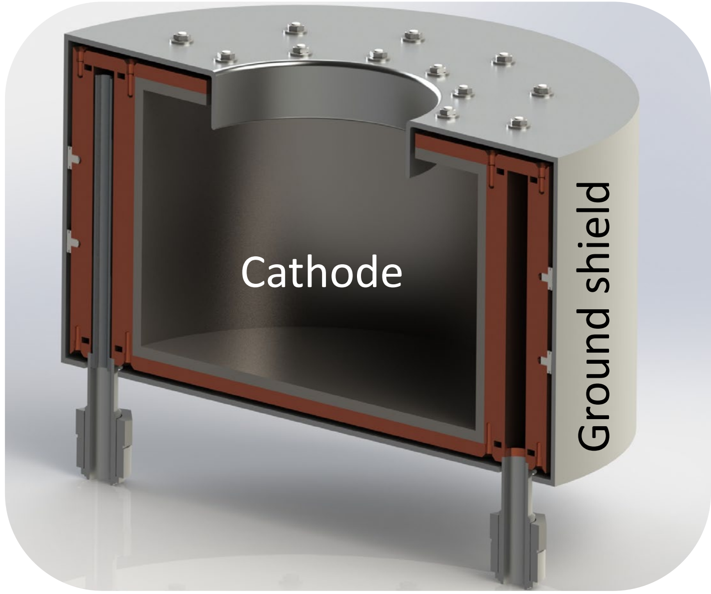


[Kotliarenko et al., Applied Science 2021]

Growing beheviour of MS and Diode depositions

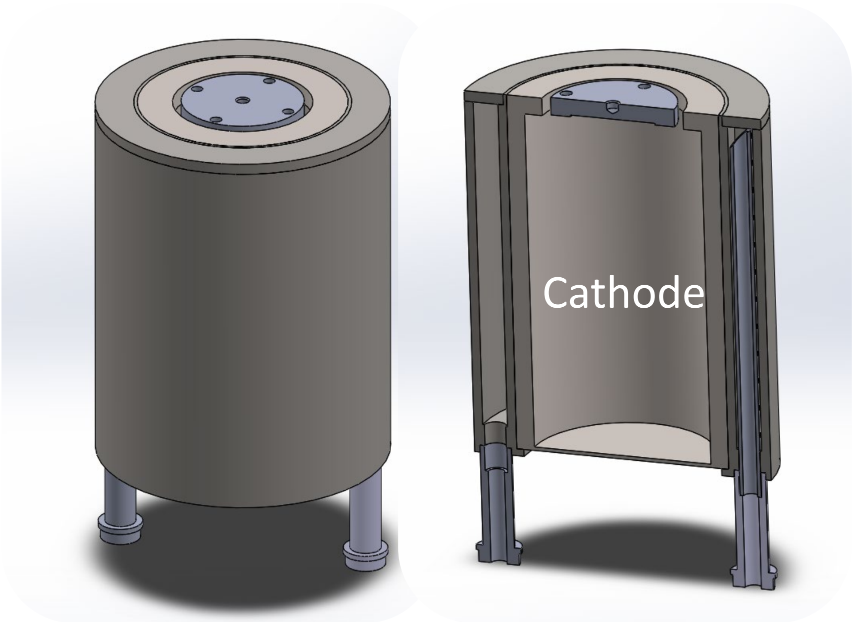
2 Inverted magnetron idea

Initial design



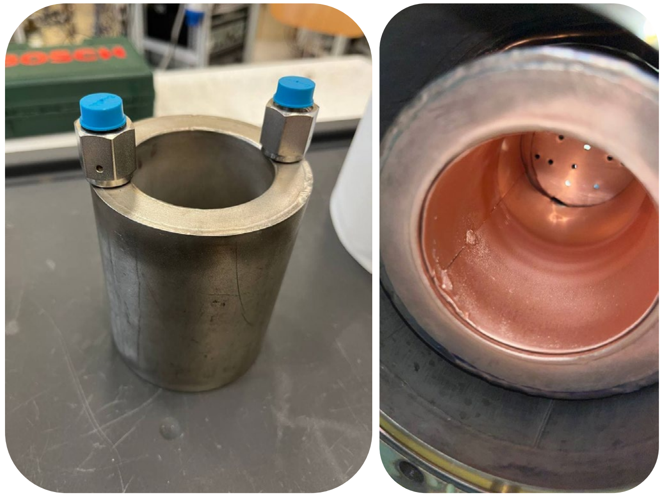
Dimensions:
External **h** 80 mm **Ø** 160 mm
Cathode **h** 60 mm **Ø** 100 mm

Prototype design



- Simpler system
- Does not require shielding
- Easy maintenance

Produced prototype



Dimensions:
External **h** 106 mm **Ø** 89 mm
Cathode **h** 106 mm **Ø** 59 mm

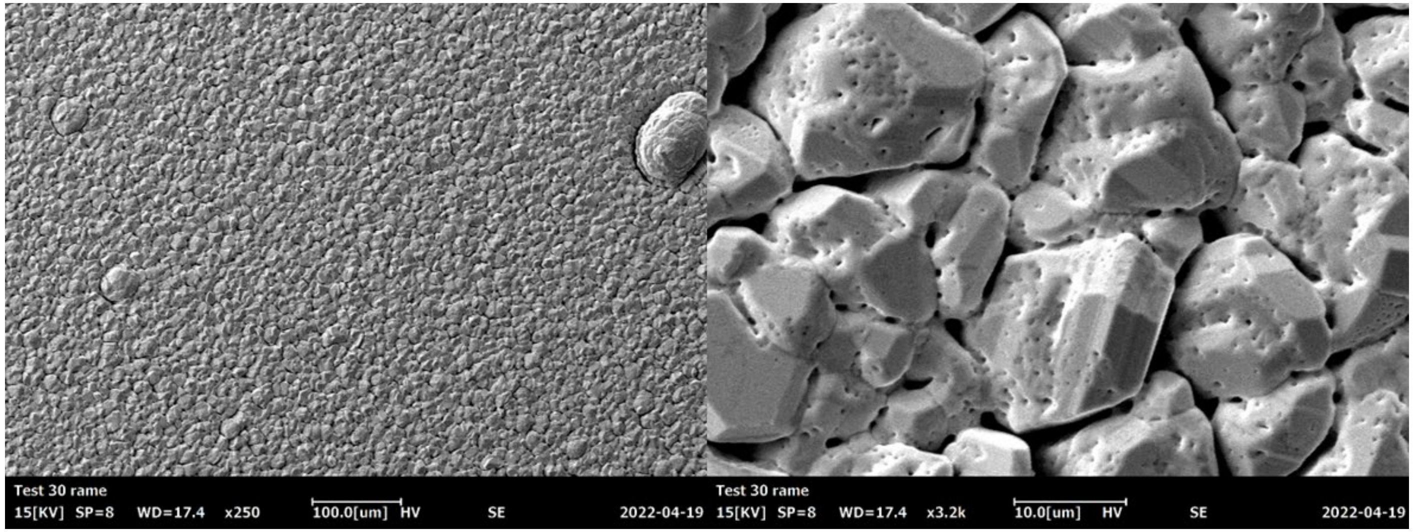
2 Inverted magnetron - proof of concept

DONE

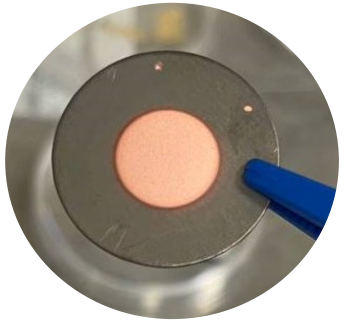
TEST 30

Deposition parameters

Gas flows: Ar – 3,5 sccm
Power: I_{const} 1 A;
U ~500 V
Time: 150 min
Coil power: 5,5 A



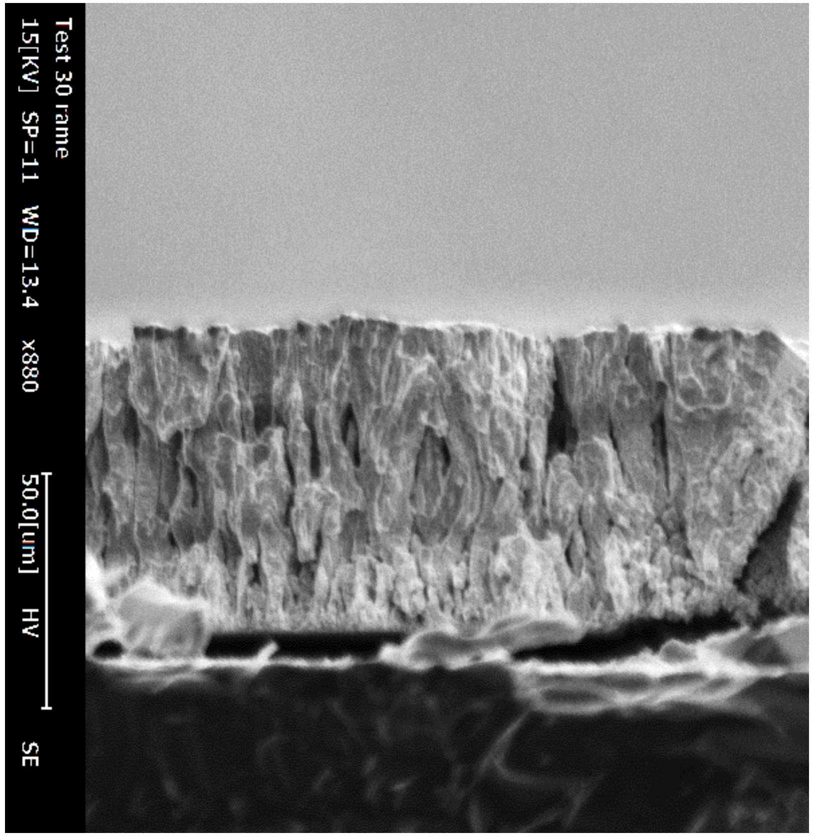
Morphology of Cu deposition



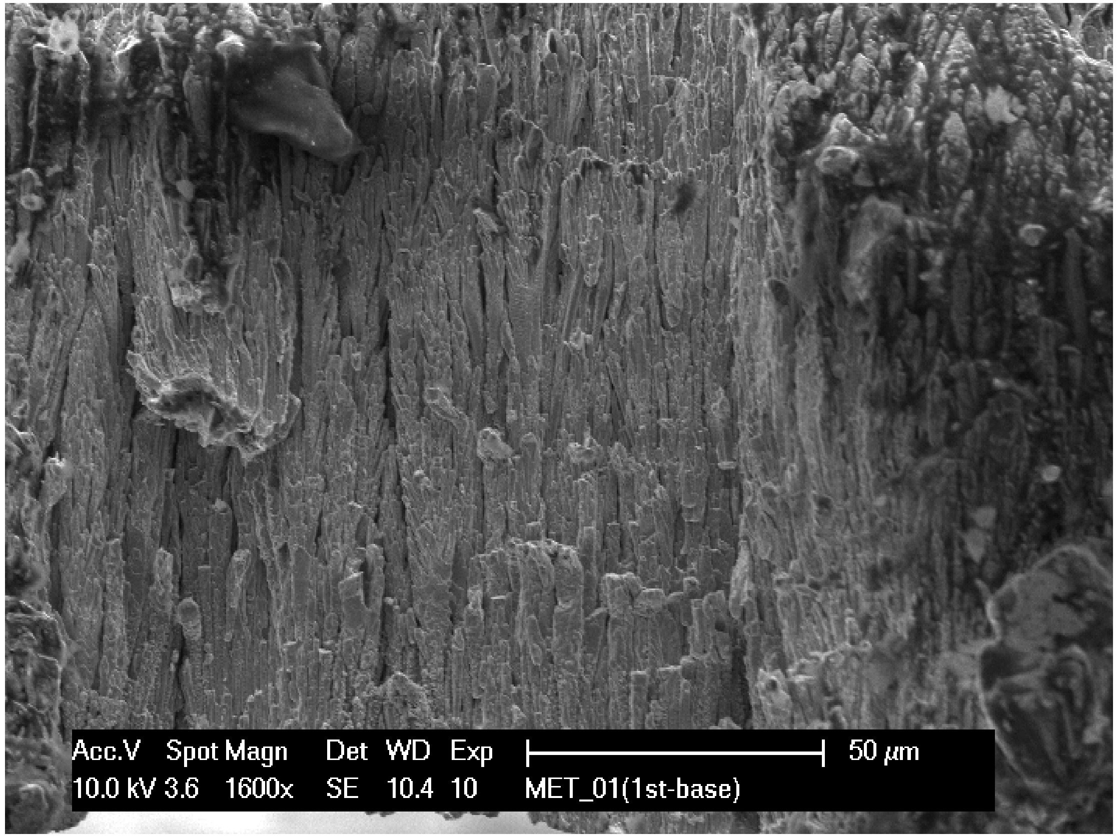
Cu deposition:
Ø10 mm x 40 µm
Nb: Ø24 x 0,5 mm

2 Inverted magnetron – standart magnetron

Inverted MS



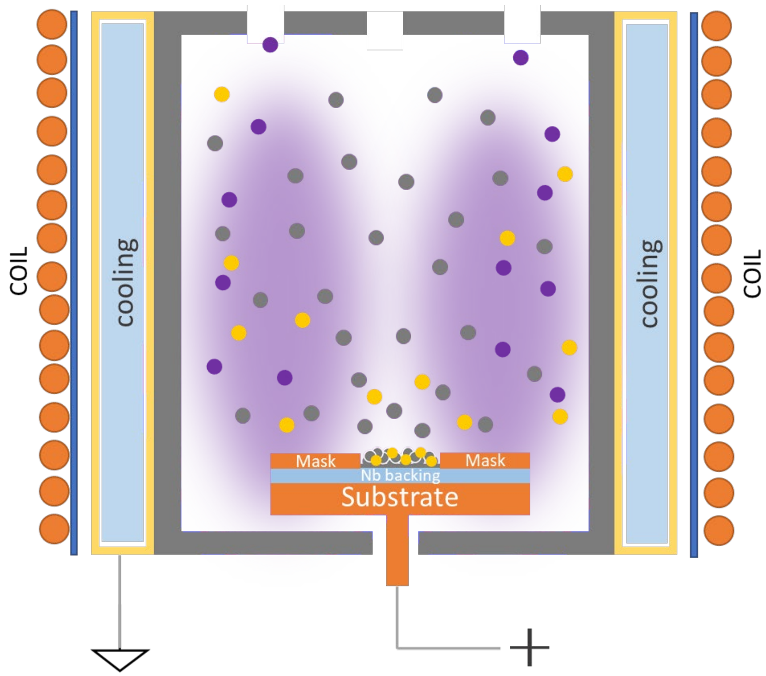
Standard MS



Growing beheviour of Cu deposition

3 nat-ZnO deposition test

Reactive sputtering process



Zn cathode

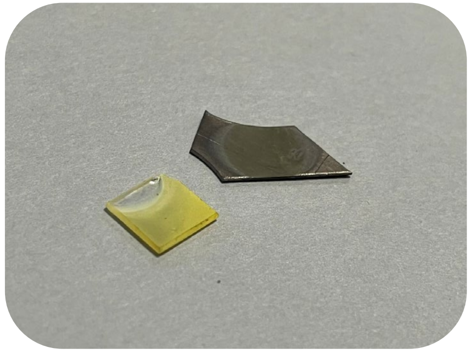
Reactive gas – O_2

Reactive process of ZnO

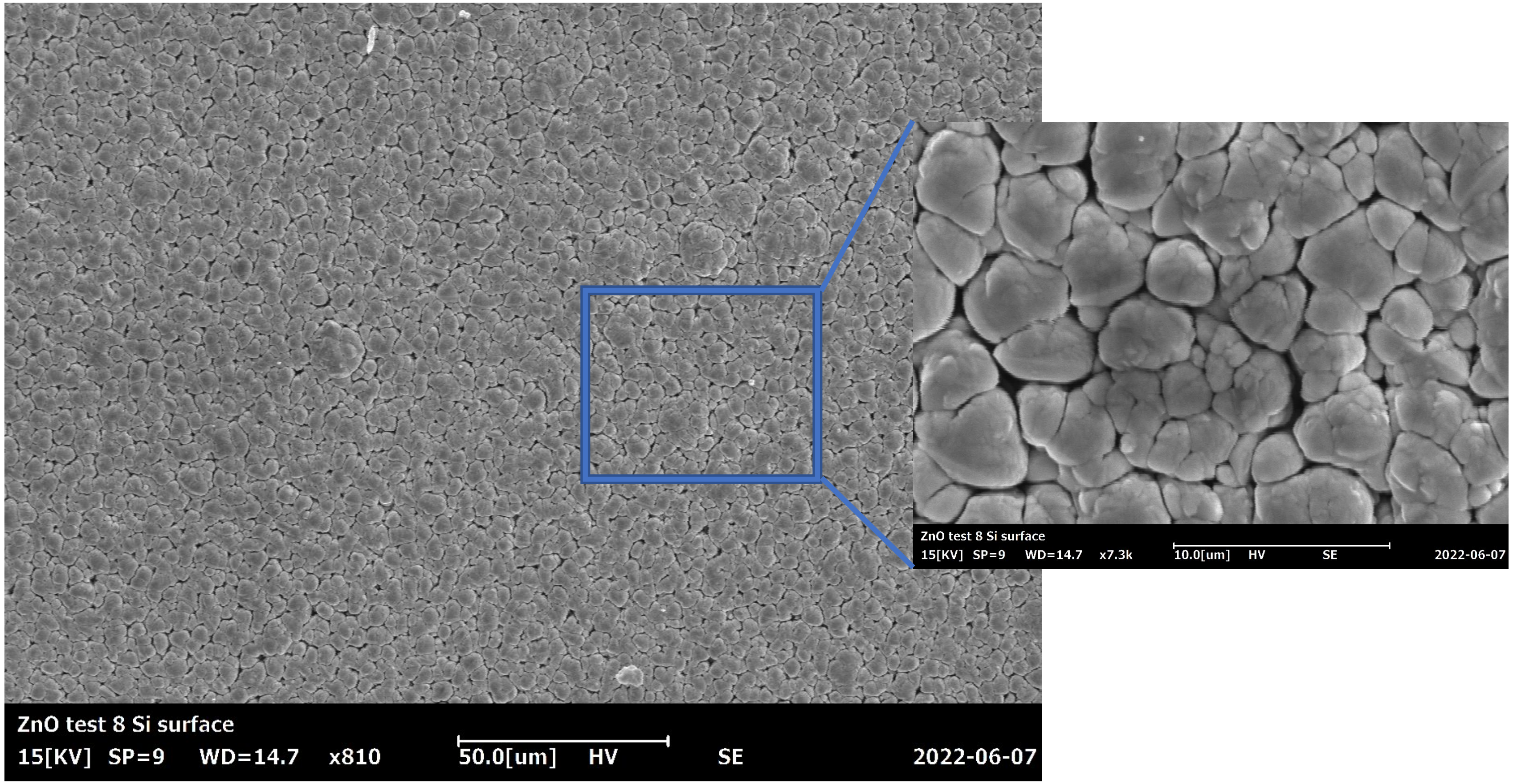
3 nat-ZnO deposition test - results

TEST ZnO - 8

Gas flows: Ar - 4 sccm
O_2 - 2 sccm
Power: I_{const} 0,7 A;
U ~450 V
Time: 115 min
Coil power: 6 A



Morphology of ZnO deposition



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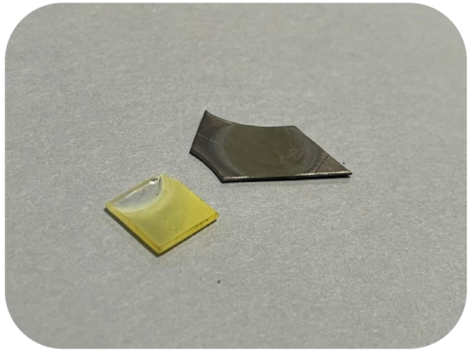
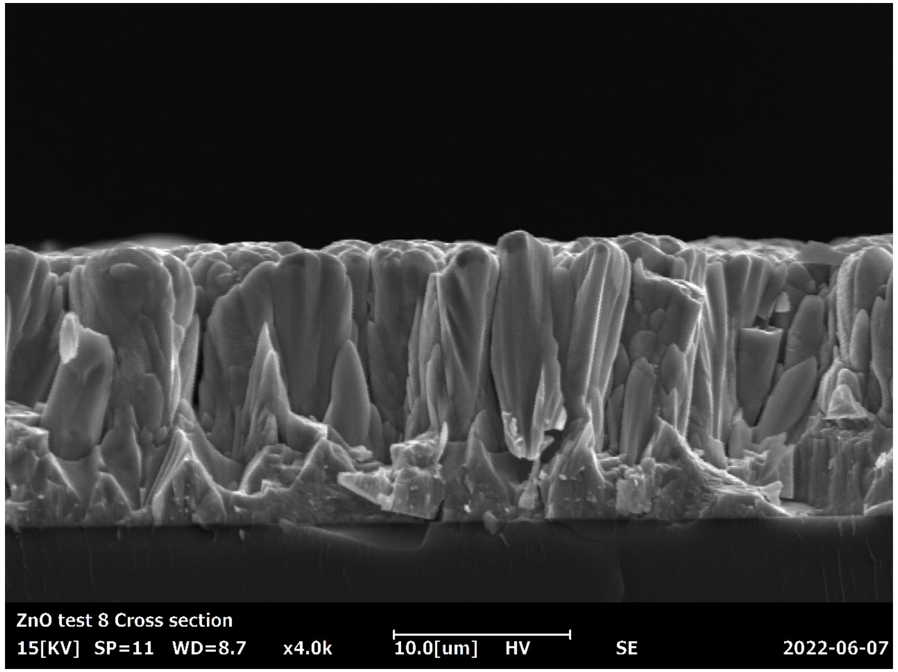
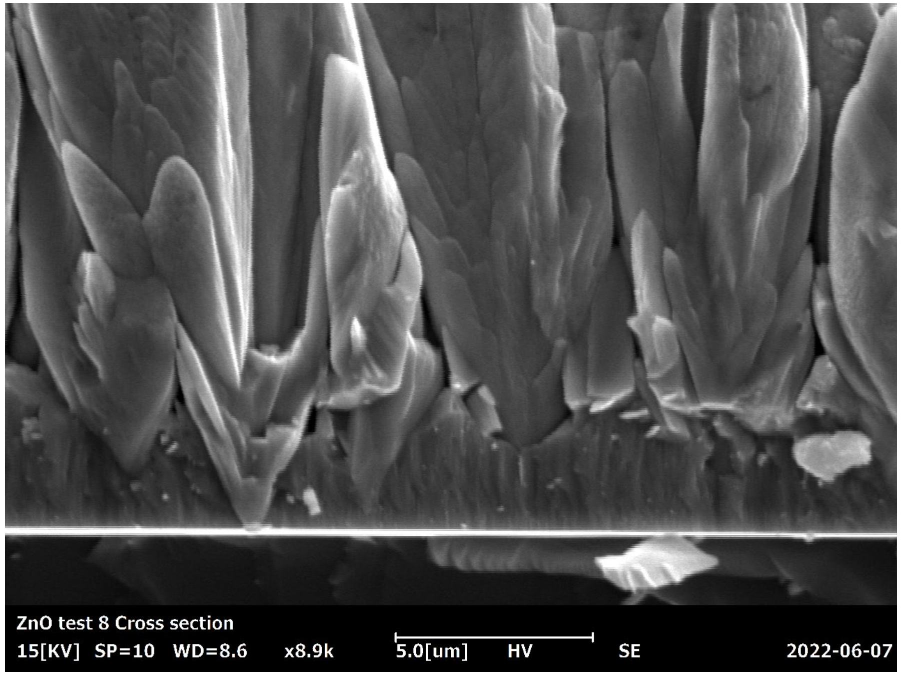


Deposition rate: 130 nm/min

Polycristalline growing beheviour of ZnO deposition

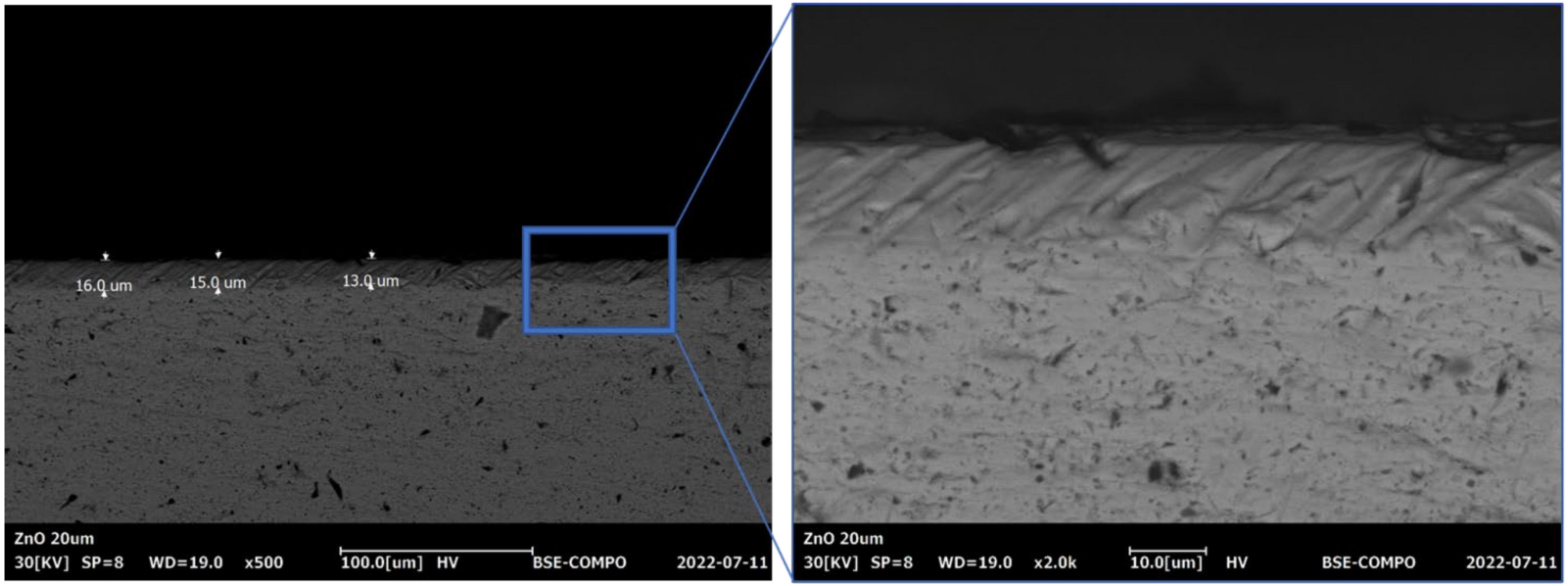




3 nat-ZnO deposition test - results

Sample preparation
Cutting with electro erosion and step-lapping with different abrasive papers

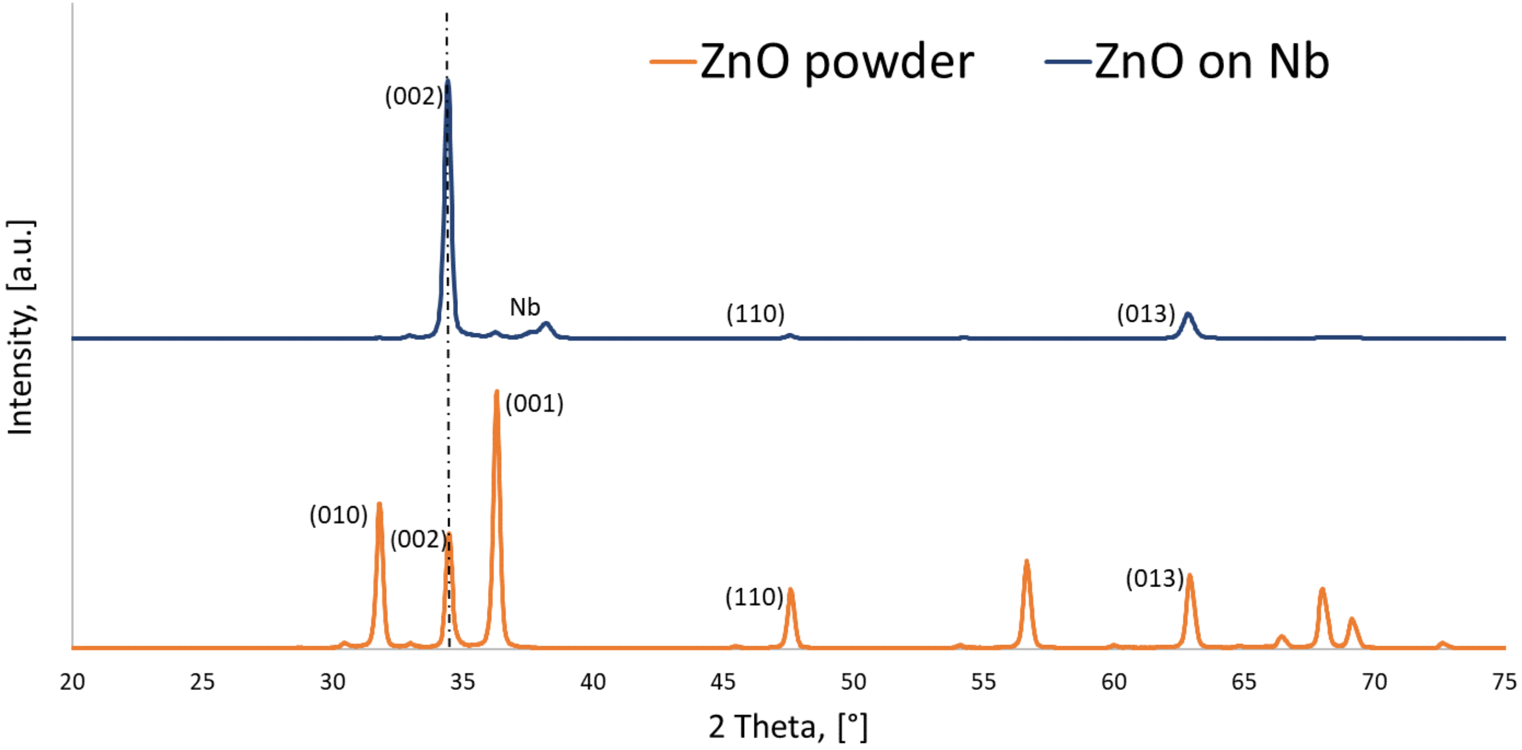
Interface analysis



High adhesion of ZnO to Nb

3 nat-ZnO deposition test - results

- Crystalline structure
- Similar to nat-ZnO powder
- Preferential (002) crystal growing



XRD diffractogram

3 nat-ZnO deposition test - results

Sputtering parameters

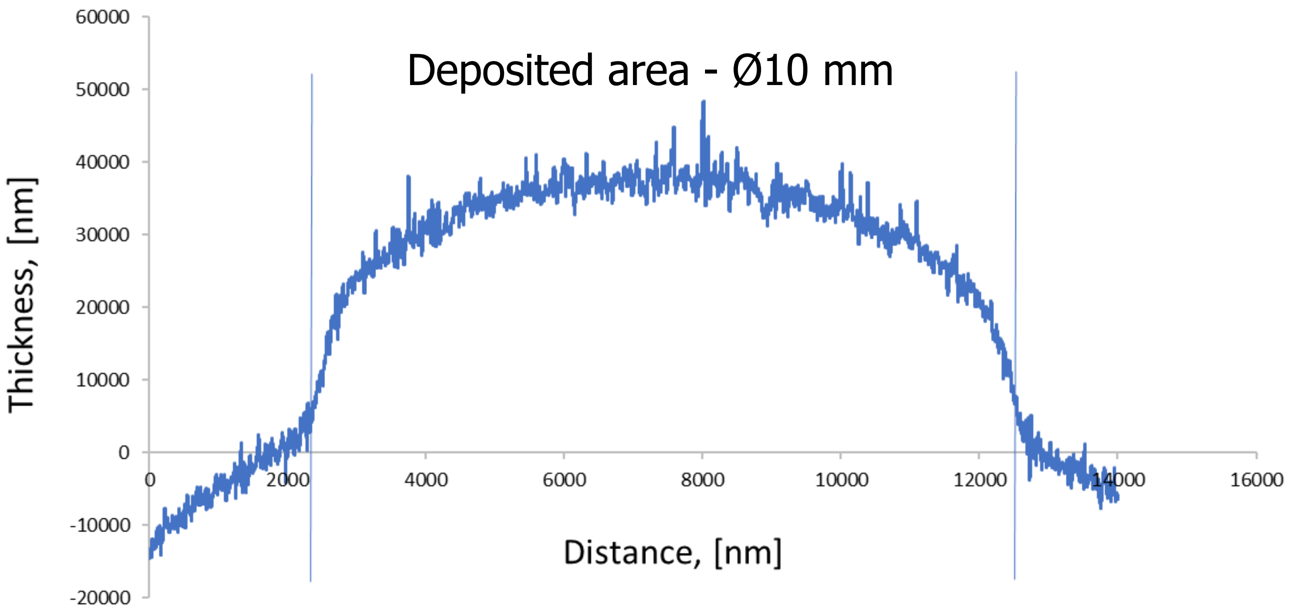
Gas flows: Ar - 4 sccm
O_2 - 2 sccm
Power: I_{const} 0,7 A;
U ~450 V
Time: 130 min
Coil power: 6 A

20 µm

Gas flows: Ar - 4 sccm
O_2 - 2 sccm
Power: I_{const} 0,7 A;
U ~500 V
Time: 150 min
Coil power: 6 A

30 µm

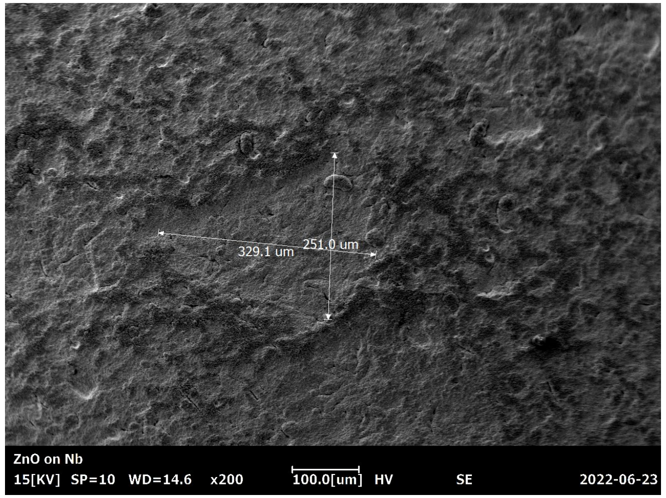
Thickness uniformity measurements by profilometer

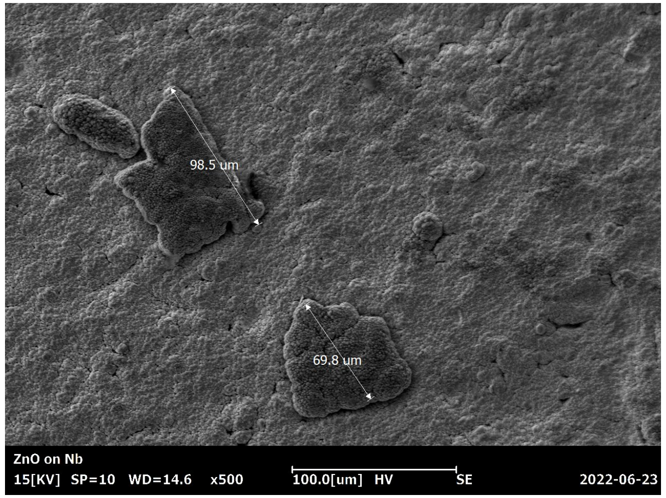


3 nat-ZnO deposition test - results

Targets parameter

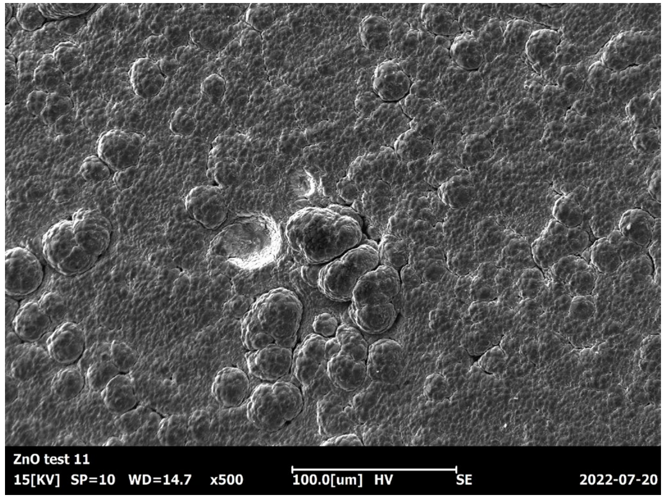
ZnO deposition:
Ø10 mm x 20 μm;
ρ_{ZnO}~ **73 %** bulk
Nb: Ø23.7 x 1,2 mm
Areal ρ ~ 8,4 mg/cm^2

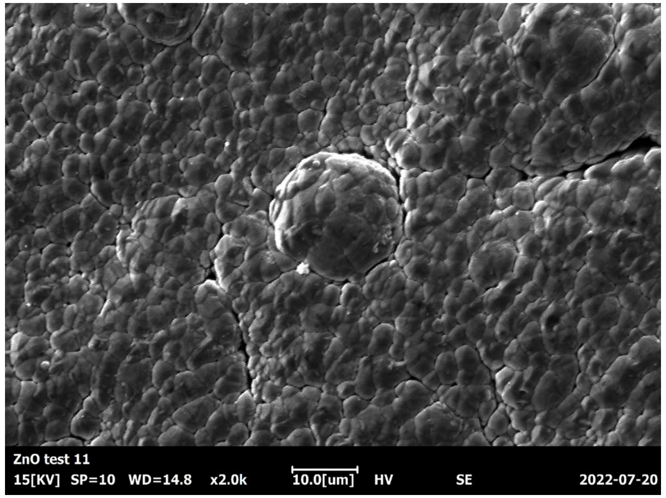




Morphology of ZnO targets

ZnO deposition:
Ø10 mm x 30 μm;
ρ_{ZnO}~ **71 %** bulk
Nb: Ø23.7 x 1,2 mm
Areal ρ ~ 12,1 mg/cm^2





3 nat-ZnO deposition test – irradiation

Targets parameter | Irradiation parameter | Thermo-mechanical irradiations tests

ZnO deposition:
Ø10 mm x 20 µm;
ρ_{ZnO}~ **73 %** bulk
Nb: Ø23.7 x 1,2 mm
Areal ρ ~ 8,4 mg/cm^2

Energy 19 MeV,
p+ current 10 µA
5 min

✓

ZnO deposition:
Ø10 mm x 30 µm;
ρ_{ZnO}~ **71 %** bulk
Nb: Ø23.7 x 1,2 mm
Areal ρ ~ 12,1 mg/cm^2

Energy 19 MeV,
p+ current 20 µA
5 min

✓

Conclusions

- Evaluation of sputtering techniques from the material point of view
- Realization of recovering shield for standard magnetron deposition

- An alternative sputtering configuration proposed and realized
- First nat-ZnO targets realization by inverted magnetron technique

Is the magnetron sputtering technique suitable for ZnO target production?

Thank you for your attention!

Conclusions

- Evaluation of sputtering techniques from the material point of view
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LARAMED

Is the magnetron sputtering technique suitable for ZnO target production?

WORK IN PROGRESS

Thank you for your attention!