Measurement of collimator block irradiated samples - status and plans

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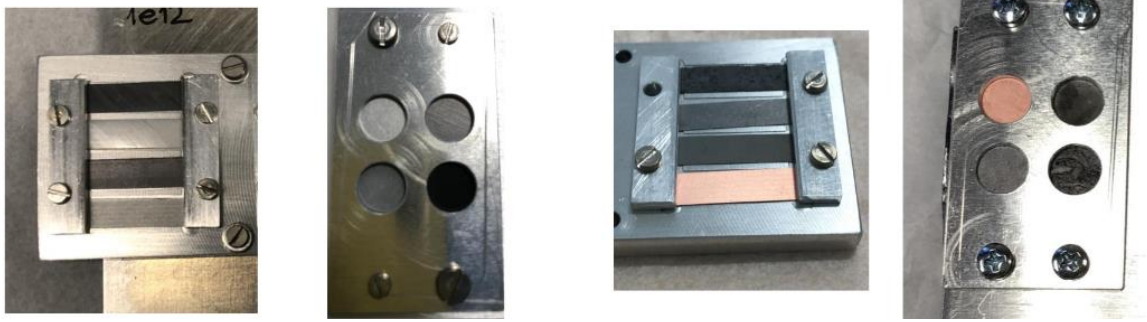
WP2 meeting, 28-04-2020

Status and plan of irradiation campaign

- Proton irradiation at BNL-2018 ✓
  - Irradiated. Tests pending (capsule to be shipped to company).
  - Company has no expertise to access resistivity (microstructure observation).
  - No resistivity test done or foreseen (contract closed).
- Ion irradiation at GSI-2019 ✓
  - Irradiated and tested (DC-RF resistivity + SEM-FIB)
  - C.Accettura in ColUSM #119 for details
  - Updated analysis → see next slides
- Ion irradiation at GSI-2020
  - Postponed (likely 1st quarter 2021).
  - C.Accettura in COLUSM #123 for details
  - Purpose: more statistics than GSI-2019, effect of fluxes.
  - Resistivity tests in DC. To be checked for RF.
- Proton irradiation at BNL-2020
  - Samples under preparation to be tested before (CERN) / after (company) irradiation.
  - Timescale > 1y due to radioactivity.

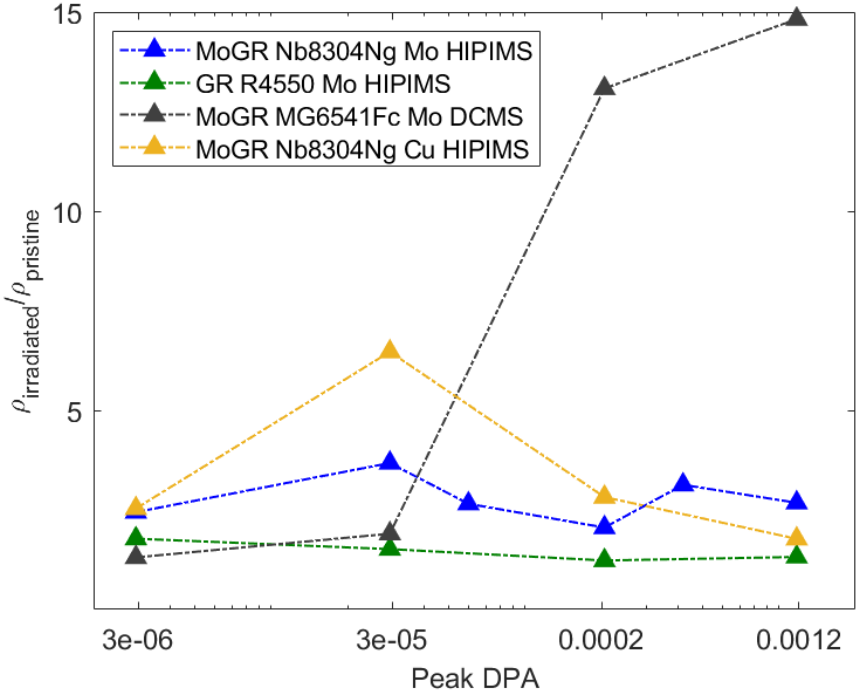
Resistivity assessment on GSI samples

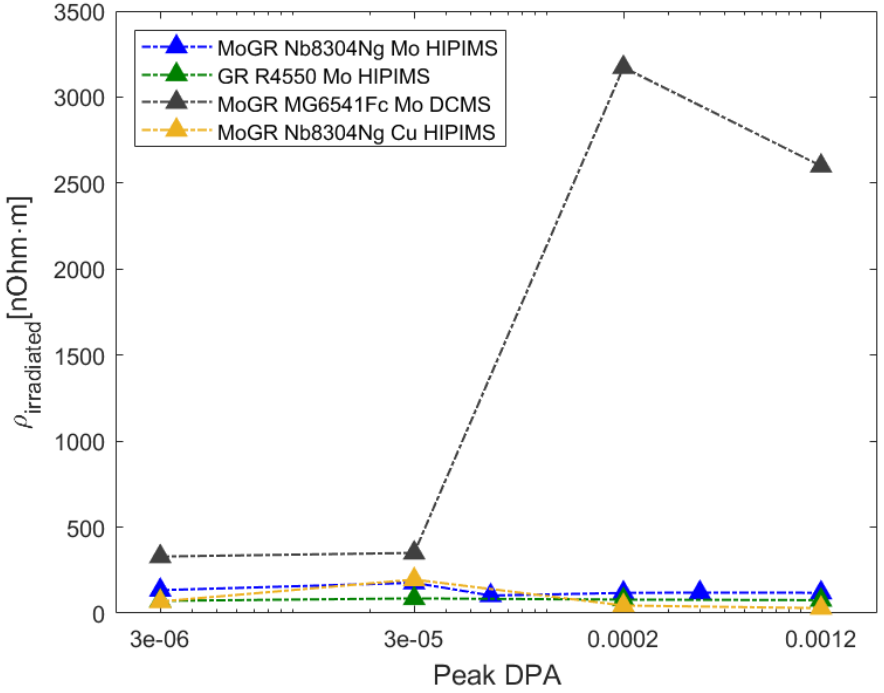
- Samples of GSI 2019 campaign available and tested in DC and RF (H011 cavity).



- All samples irradiated at 4 fluences: 1e12, 1e13, 7e13, 4e14
- Analysis update:
  1. Electrical resistivity comparison HIPIMS and DCSM (DC/RF)
  2. Microscopic observation: Deeper knowledge of the pristine coating behavior → better comparisons

1. Electrical resistivity (DC)





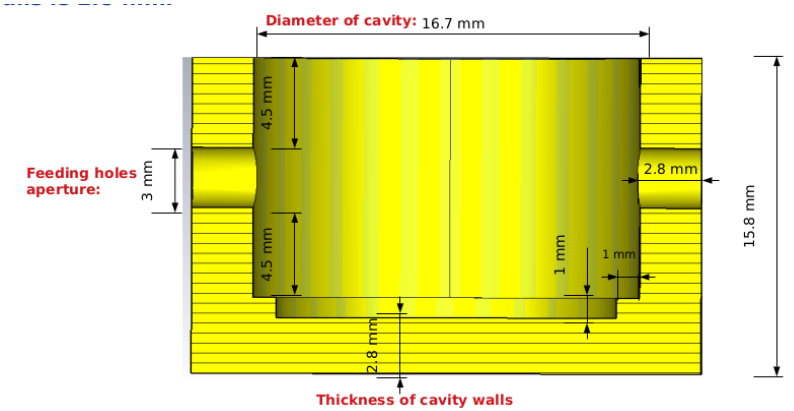
- DCMS coating more resistivity before irradiation and loosing more then HIPIMS
- HIPIMS -> x2-3 after irradiation, no dependence on fluence.
- Uncertainty being evaluated.

Possible explanation: DCMS has lower grain connection → trapping of radiation-induced defects that hinders defect recombination

1. Electrical resistivity (RF)

- Tested already with large cavity: aspect ratio too large → poor sensitivity.
- Smaller H011 cavity designed for BNL 2020 campaign:
  - In process of being fabricated, will be finalized when CERN re-opens.
  - Suitable for 20x20mm samples -> sensitivity ok for x2 in coating resistivity.
  - Will test BNL samples before irradiation campaign and after (> 1y later).

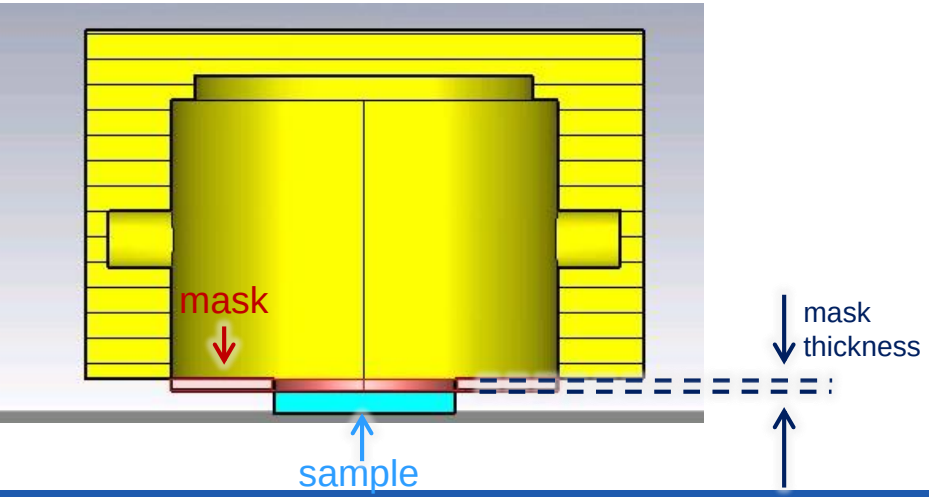
GSI sample on “large cavity”

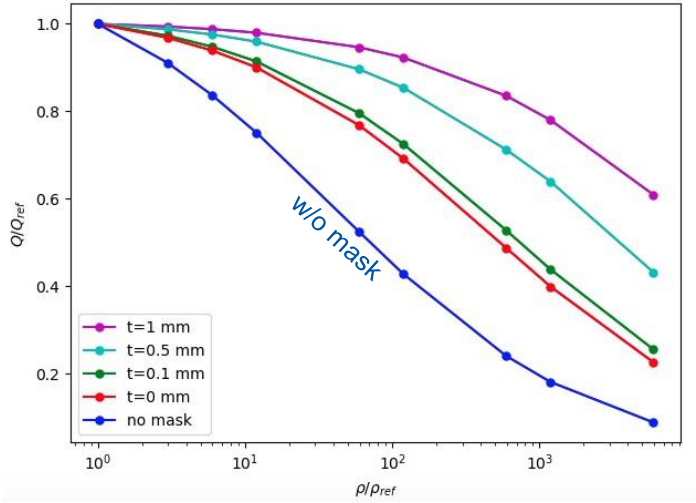


New “small” cavity for BNL samples

1. Electrical resistivity (RF)

- Tested already with large cavity: aspect ratio too large → poor sensitivity.
- Smaller H011 cavity designed for BNL 2020 campaign (thanks A.Kurtulus!):
  - In process of being fabricated, will be finalized when CERN re-opens.
  - Suitable for 20x20mm samples -> sensitivity ok for x2 in coating resistivity.
  - Will test BNL samples before irradiation campaign and after (> 1y later).
- GSI-2019 samples are Ø10mm -> a mask could be applied, sensitivity tbc.
- GSI-2020 samples are 5x20mm could be tested as well (2 samples aside).



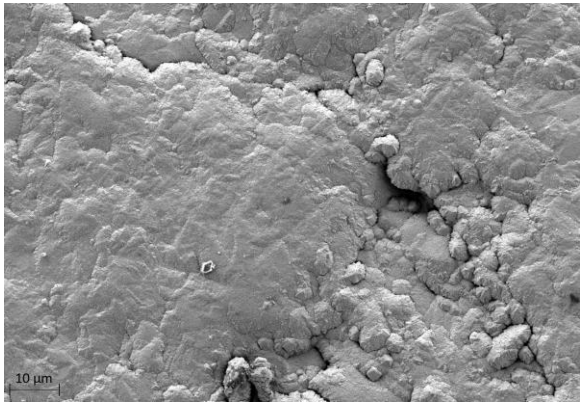


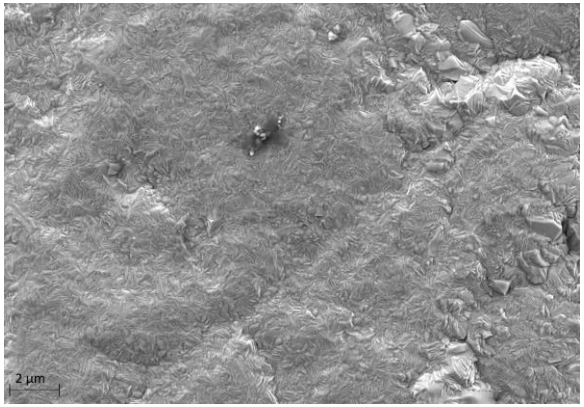
2. Microscopic observation

- Observation of Mo HIPIMS on graphite and MoGr before/after irradiation.
- Shown cases correspond to peak DPA in the coating equal to the one expected in HL-LHC.

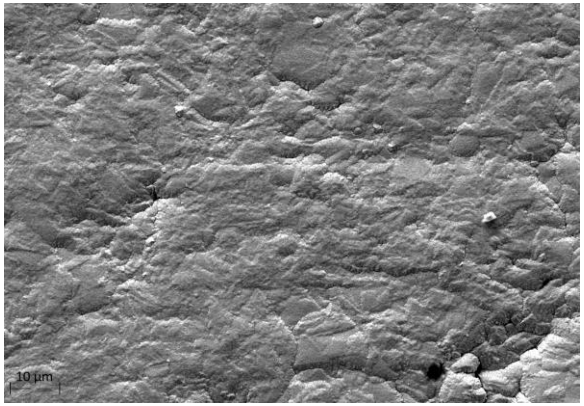
Mo on MoGr

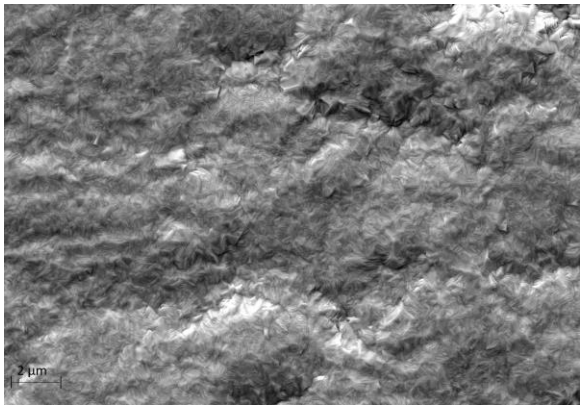
Pristine





Irradiated

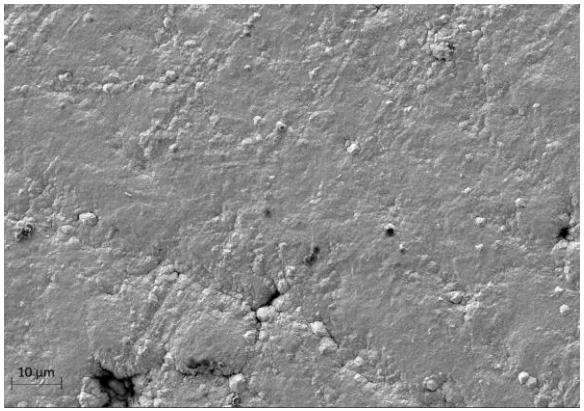


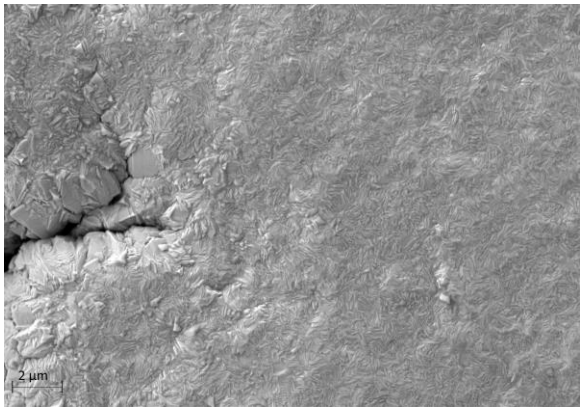


- Good grain connection and flat area also after irradiation
- Valley already present before irradiation (substrate related)

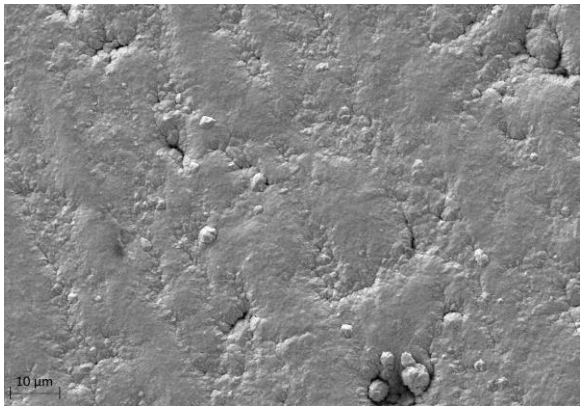
Mo on Gr

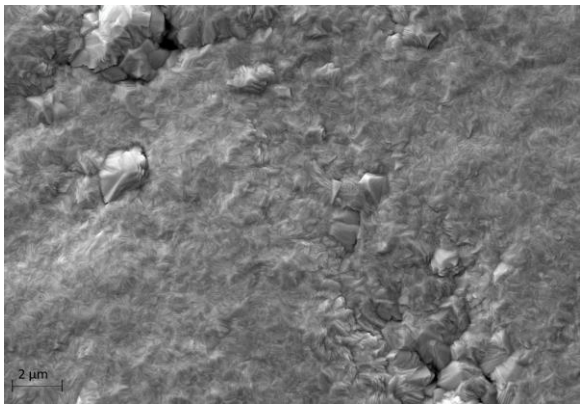
Pristine





Irradiated

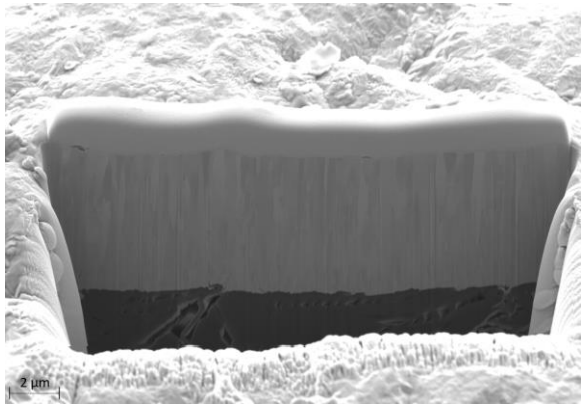




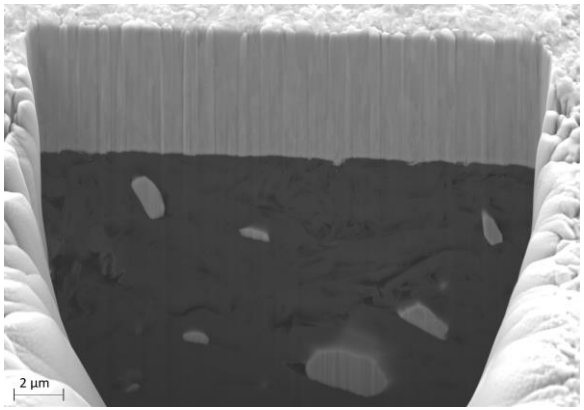
- Similar structure before and after irradiation

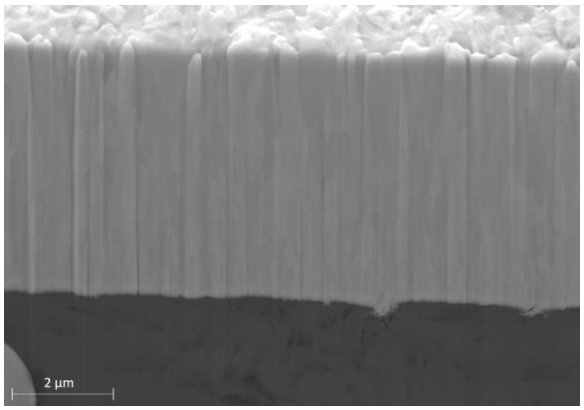
Mo on MoGr – FIB cross-section

Pristine



Irradiated

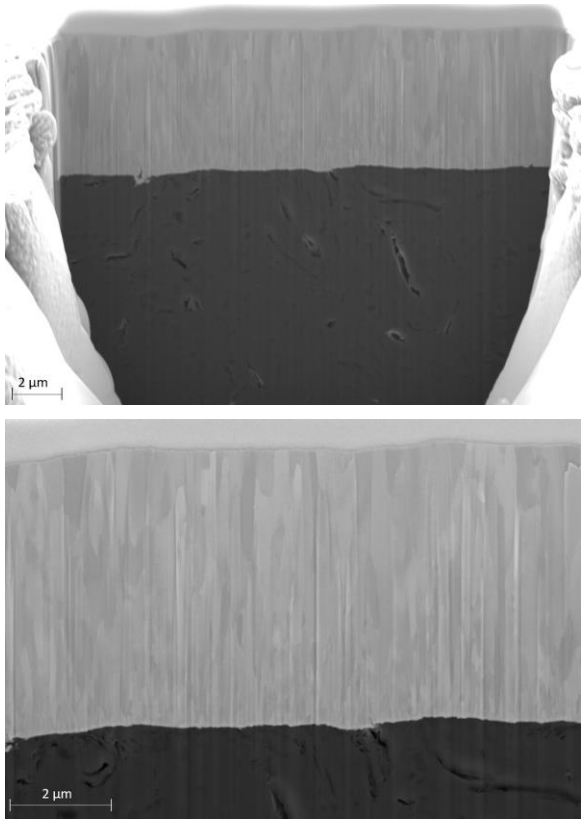




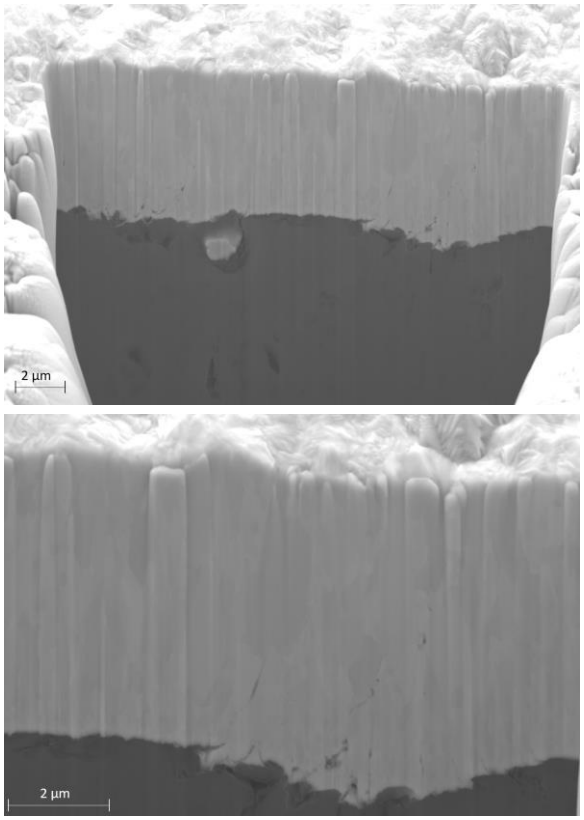
- Columnar and dense structure kept after irradiation
- No cracks, good contact with the bulk
- Same coating thickness (applied tilt correction factor on SEM image)

Mo on Gr – FIB cross-section

Pristine



Irradiated



- Columnar and dense structure kept after irradiation
- Some cracks observed: sometimes present in pristine material due to the bulk → cannot be directly linked to irradiation

Summary

- Detailed plan for irradiated samples test both at GSI and BNL.
- Updated analysis of GSI-2019 samples:
  - Mo resistivity measured in DC suggests factor 2-3 increase due to radiation for HIPIMS coating of Mo on MoGr. Uncertainty tbc.
  - SEM-FIB: No significant change in microstructure.
- RF measurements planned with a new smaller H011 cavity to be fabricated once CERN reopens (thanks EN-STI!)
- To be tested on samples of:
  - GSI-2019 (need mask to reduce aperture size)
  - GSI-2020 (need mask and 2 samples aside)
  - BNL-2020 (as-it-is, method to be shared with company for after-irradiation testing)