

Measurement of collimator jaws irradiated samples - status and plans

N.Biancacci, C.Accettura, A.Baris, A.Bertarelli, F.Carra,
F.Caspers, A.Kurtulus, R.Illan Fiastre, I.Llamas Garcia, E.Métral,
R.Perez Martinez, S.Redaeli, B.Salvant

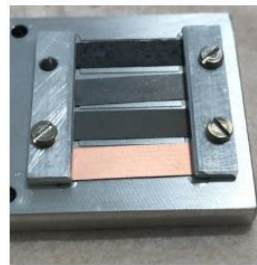
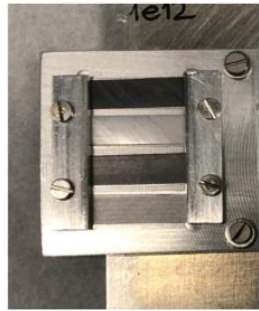
WP2 meeting, 21-04-2020

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 CoIUSM #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.

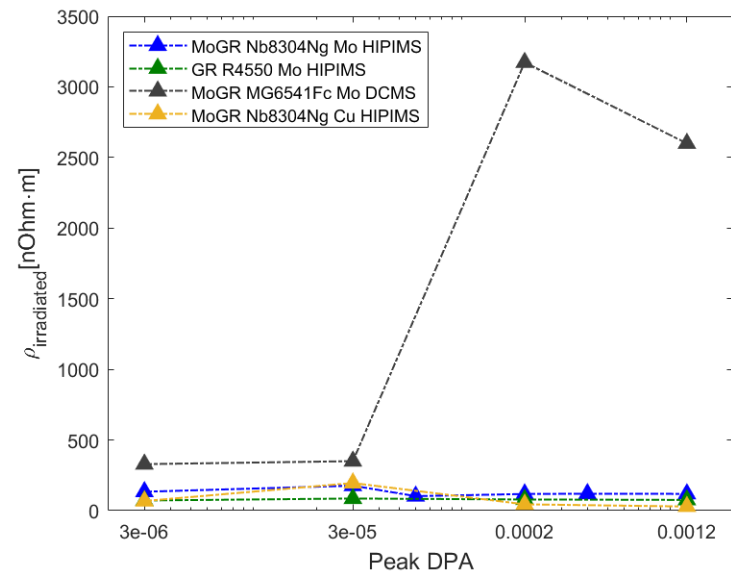
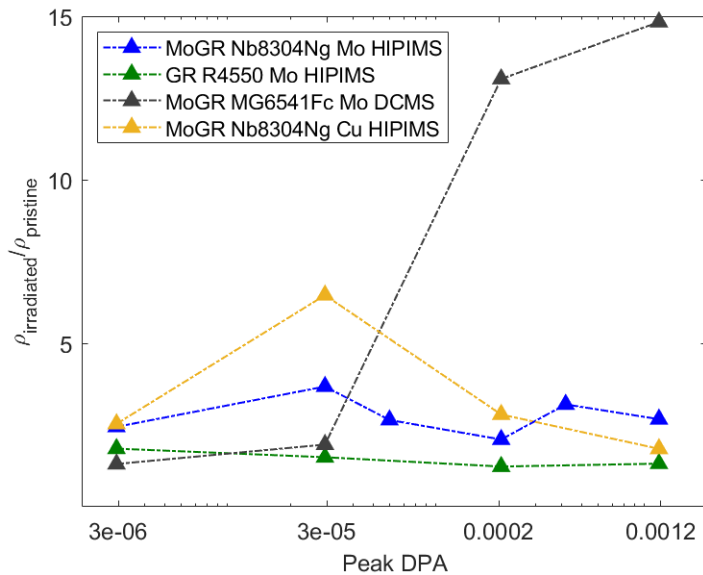
Resistivity assessment on GSI samples

- Samples of GSI 2019 campaign available and tested in DC and RF (H011 cavity).
- Two sizes: $\varnothing 10\text{mm}$ disks and $5 \times 20\text{mm}$ stripes.



- 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 Mo on MoGr** → more resistive before irradiation and losing more than HIPIMS
 - **HIPIMS Mo on MoGr** → x2-3 after irradiation, no dependence on fluence.
 - **HIPIMS Mo on Gr** → x2 after irradiation, no dependence on fluence.
- >> **Uncertainty being evaluated:** more statistics with GSI-2020 campaign will help.

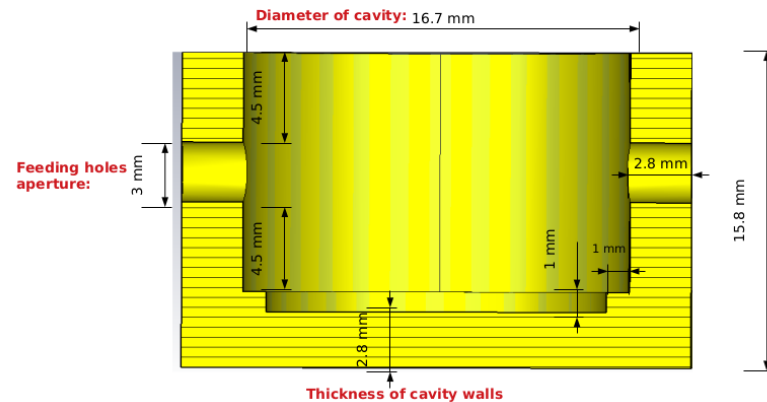
DCMS/HIPIMS possible explanation: DCMS lower grain connection → trapping of radiation-induced defects that prevents defect recombination.

1. Electrical resistivity (RF)

- Tested already with large cavity: aspect ratio too large → poor sensitivity.
- **Smaller H011 cavity designed for BNL 2020 campaign** (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).



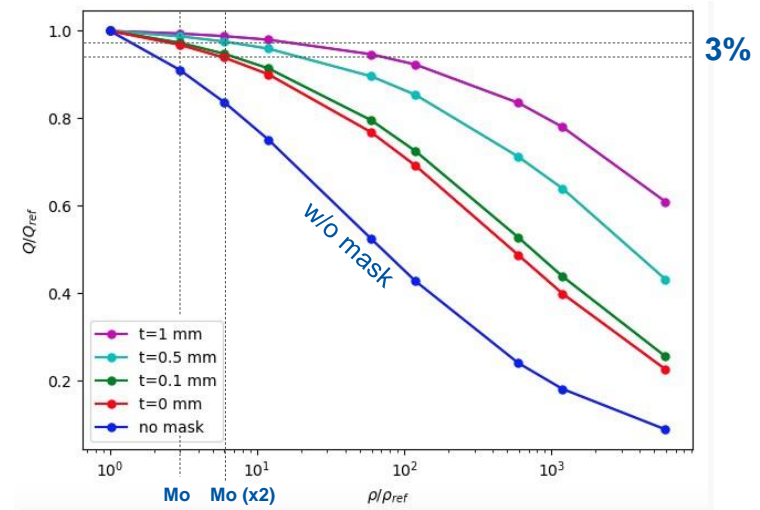
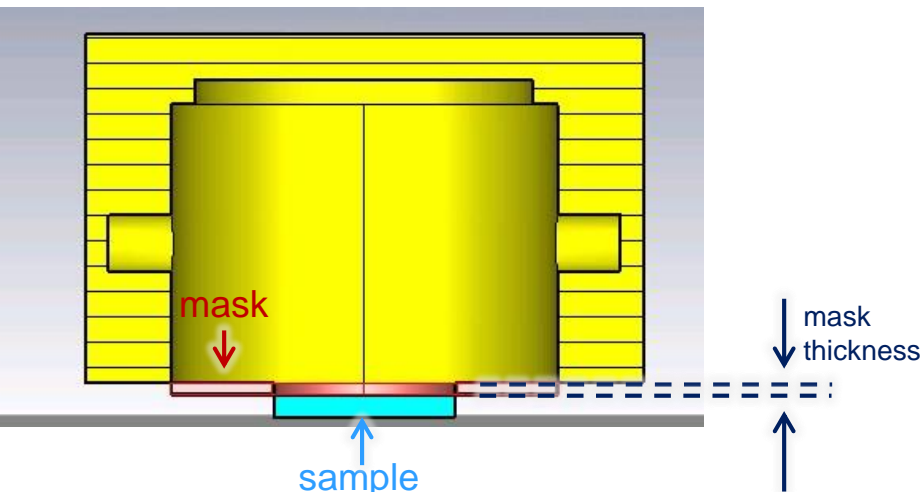
GSI sample on “large cavity”



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 $\varnothing 10\text{mm}$
 - A **mask could be applied** → ~3% sensitivity to detect x2 Mo.
- **GSI-2020 samples** are 5x20mm could be tested as well (2 samples aside).

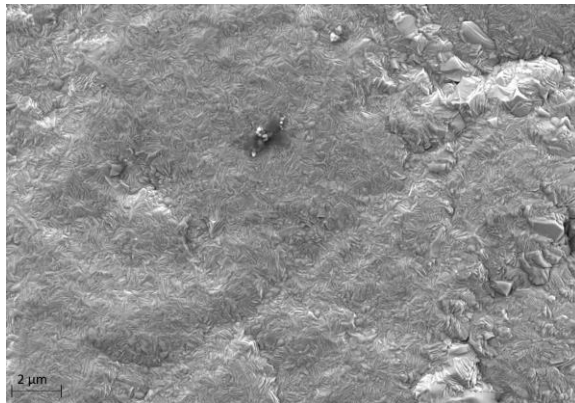
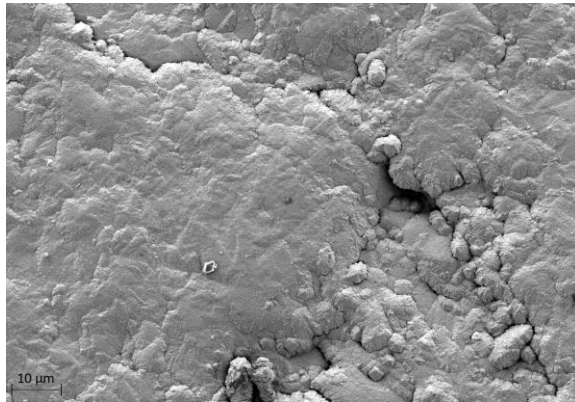


2. Microscopic observation

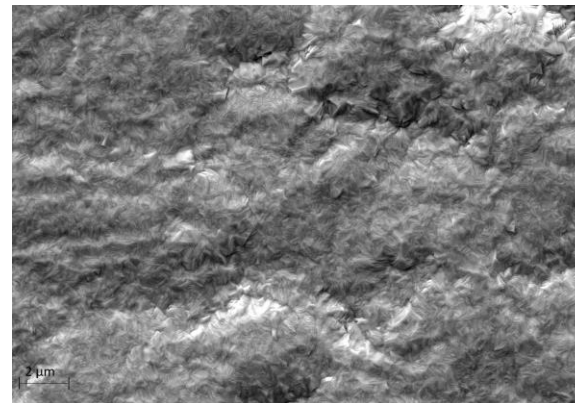
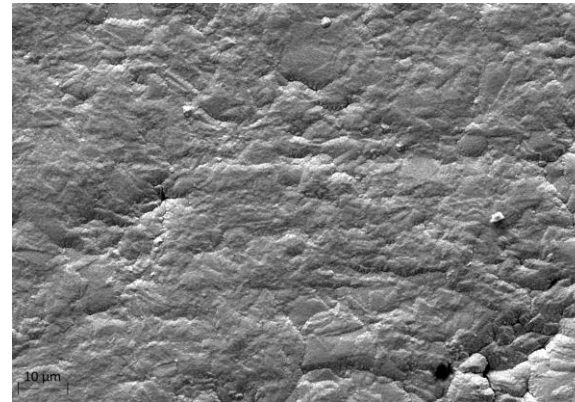
- Observation of HIPIMS Mo on MoGr/graphite before/after irradiation.
- Shown cases correspond to **peak DPA** in the coating equal to the one **expected in HL-LHC**.

Mo on MoGr

Pristine



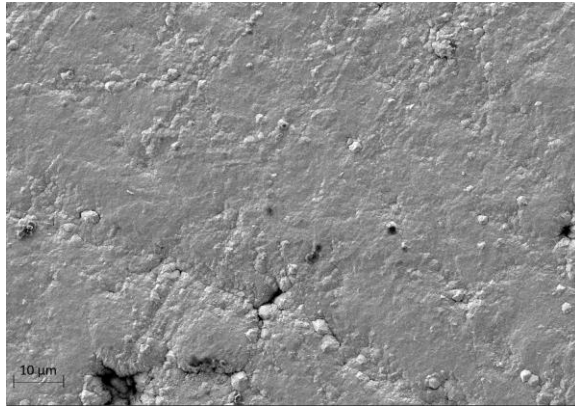
Irradiated



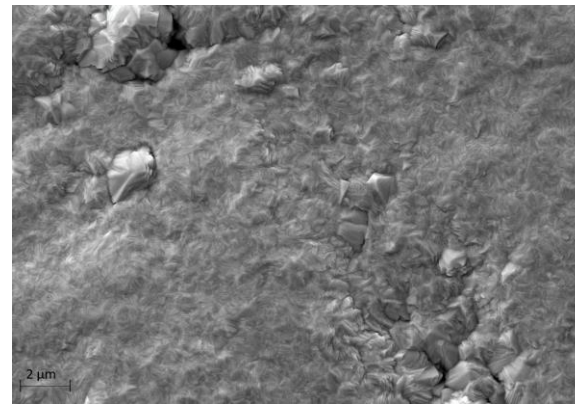
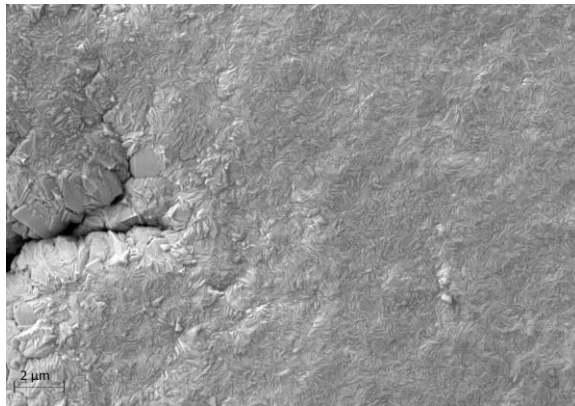
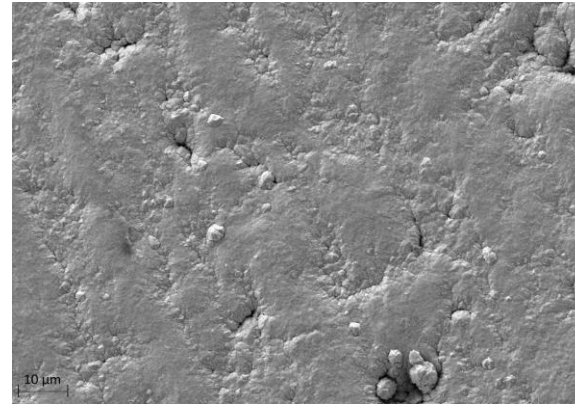
- Good grain connection and flat area also after irradiation
- Valley already present before irradiation (substrate related)

Mo on Gr

Pristine



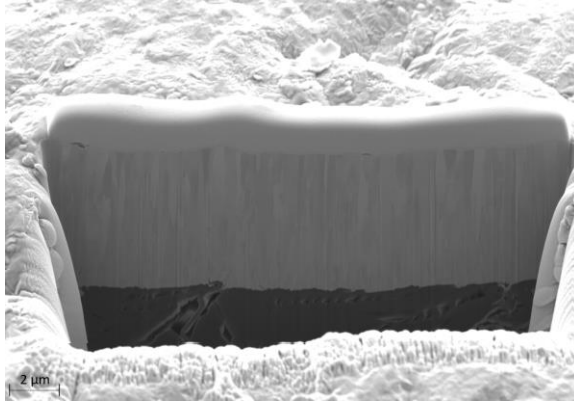
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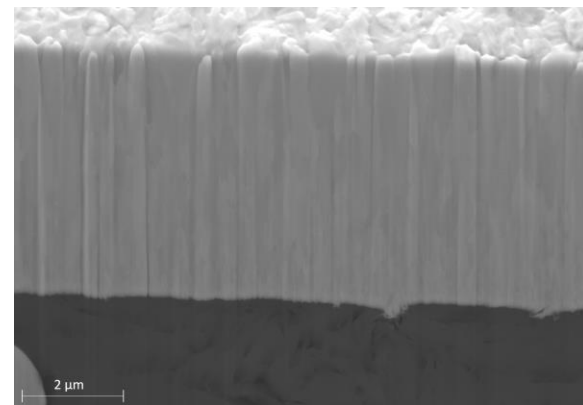
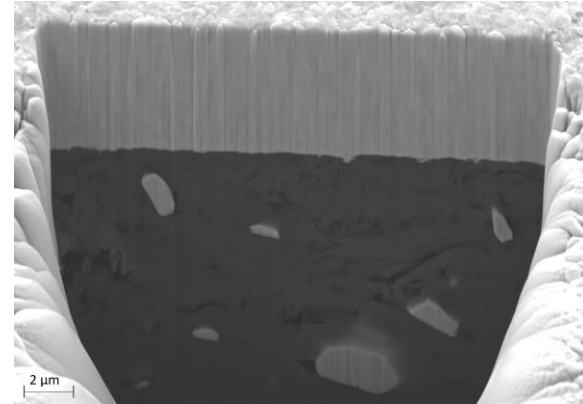
- Similar structure before and after irradiation

Mo on MoGr – FIB cross-section

Pristine



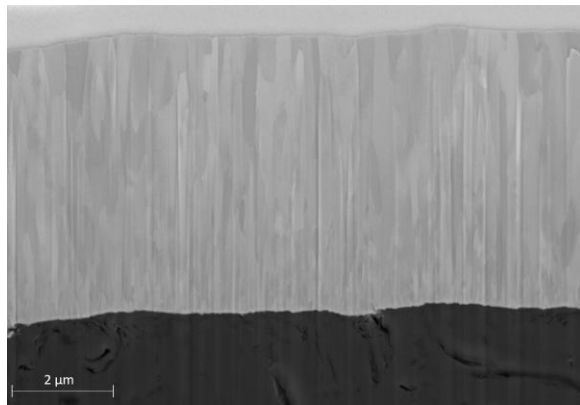
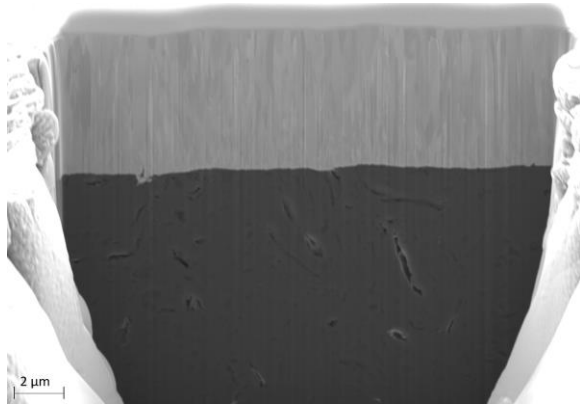
Irradiated



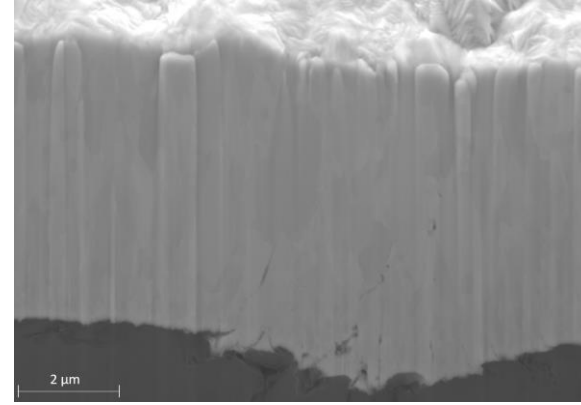
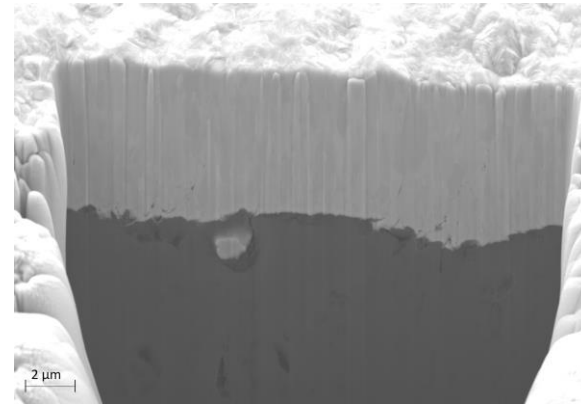
- Dense columnar structure kept also after irradiation
- No cracks, good contact with the bulk
- Same coating thickness (applied tilt correction factor on SEM image)

Mo on Gr – FIB cross-section

Pristine



Irradiated



- Dense columnar structure kept also 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)