kunaldhirajal.soni@unibas.ch

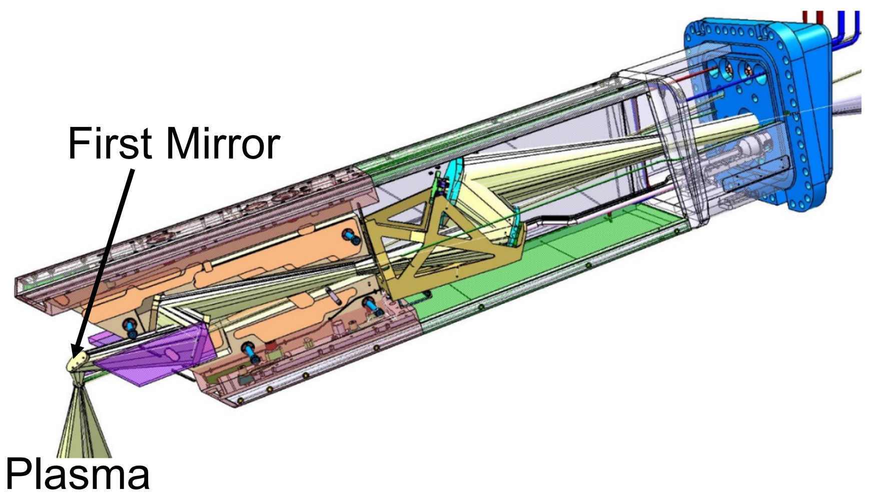
Plasma Cleaning of Steam Ingressed ITER FMs

K. Soni[1], L. Moser[1], L. Marot[1], R. Steiner[1], F. Le Guern[2], J. Piqueras[2] and E. Meyer[1]

[1]Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland
[2]F4E, c/Josep Pla 2, E-08019 Barcelona, Spain

Introduction / Motivation

- Metallic First Mirrors (FMs) will play a crucial role for ITER optical diagnostic systems.
- Being the first element of the optical path, FMs are likely to suffer from erosion and deposition which can degrade the FMs reflectivity. In addition, the FMs can be exposed to steam in the event of an in-vessel water leak leading to a degradation of their optical properties.

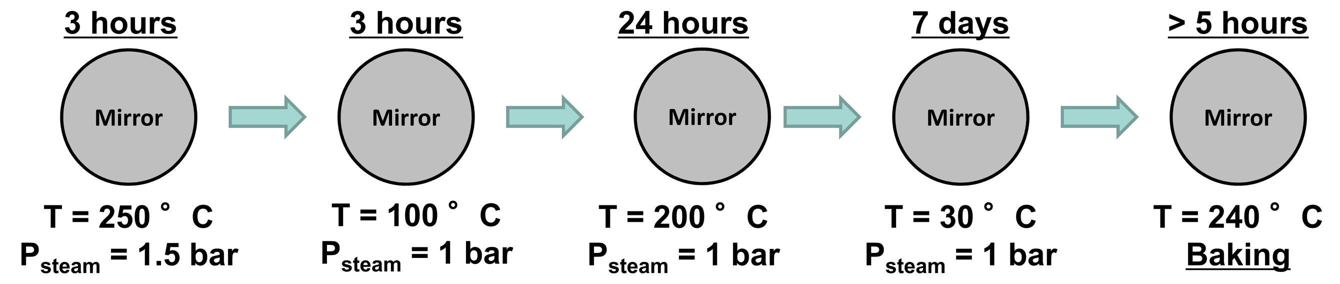


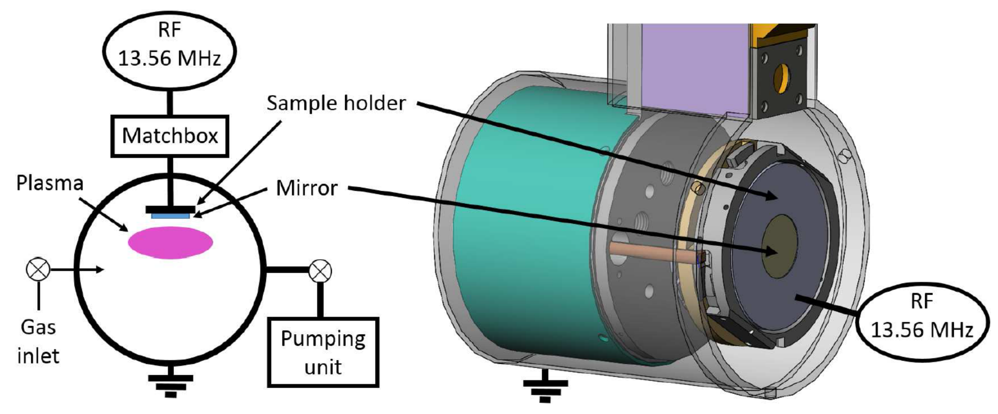
One possible optical layout of the CXRS diagnostic
With the courtesy of the CXRS diagnostic team.

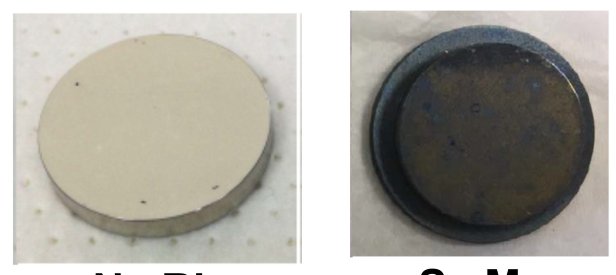
- More than 20 optical diagnostic systems using FMs are expected to need in situ plasma cleaning techniques to remove the deposits without damaging the FMs.

Experimental setup

- Steam Ingress (SI) procedure [1]







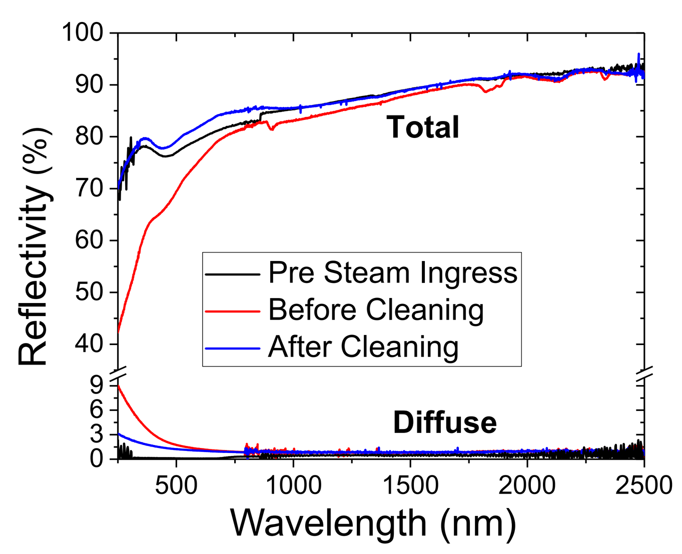
Nc Rh Sc Mo

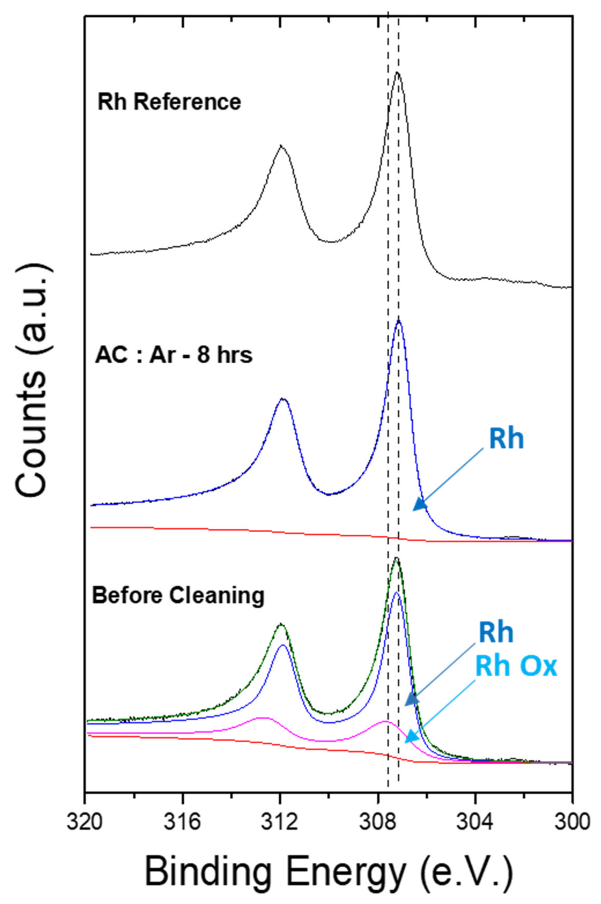
- Corroded mirrors are plasma cleaned with Ar and/or H_2 at 220 eV. The plasma is created by applying RF at 13.56 MHz directly on the mirrors.
- Plasma cleaning was done in steps followed by XPS measurements.

Results

Plasma Cleaning of Rhodium (300nm on SS)

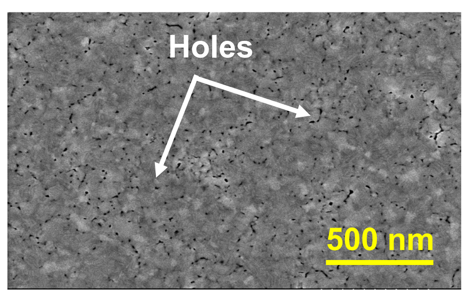
- Cleaning in Ar plasma with 13.56 MHz, 0.5 Pa at 200 V for 8 hours



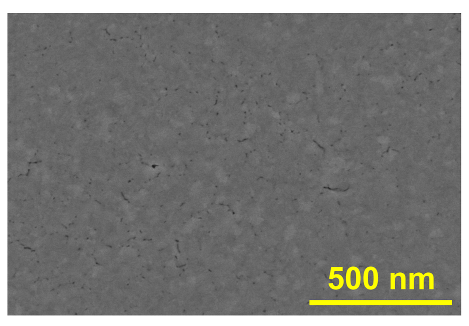


- **Total reflectivity recovered**
- **Diffuse reflectivity decreased**
- **Removal of Rh oxide**

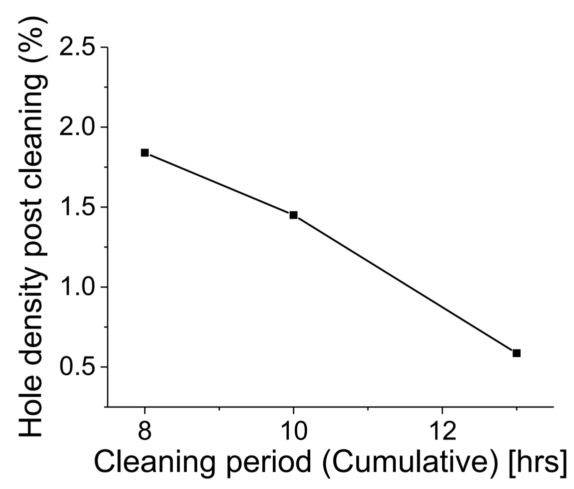
- SEM and FIB images revealed holes on the surface after cleaning.



Cleaning for 8h; Hole density **1.84%**



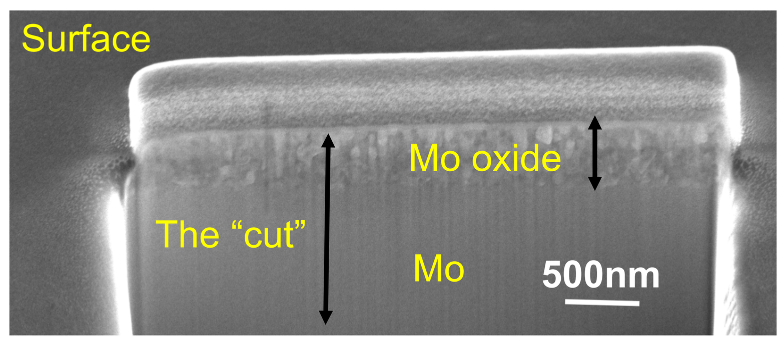
Cleaning for 13h; Hole density **0.58%**



- **The steam ingress created holes.**
- **The hole density decreases with a longer duration of plasma cleaning**

Post-steam ingress characterization of Single Crystal Mo

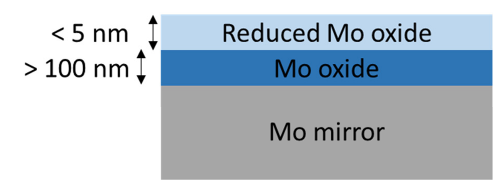
- Sharp drop in reflectivity after steam ingress
- Mo oxide estimated between **120 and 170 nm**



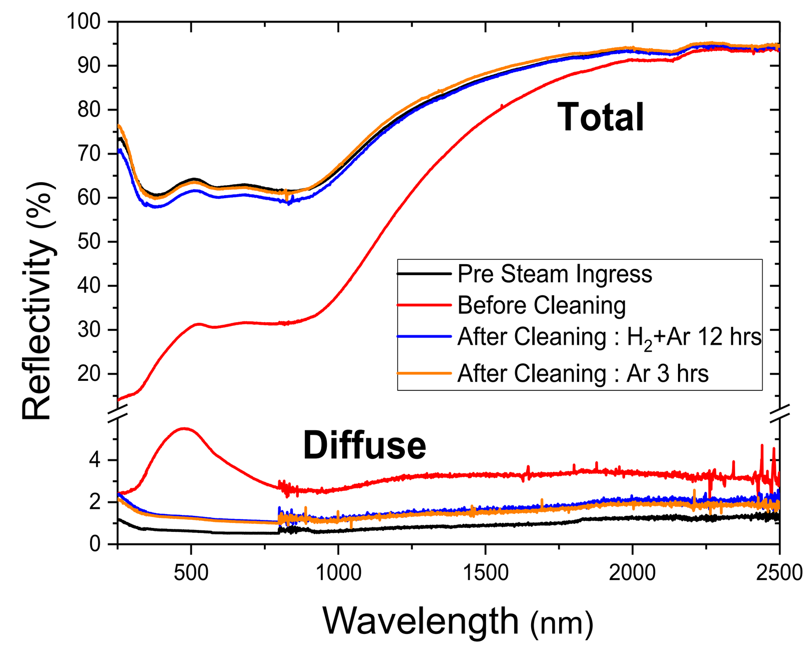
Plasma Cleaning of Single Crystal Molybdenum

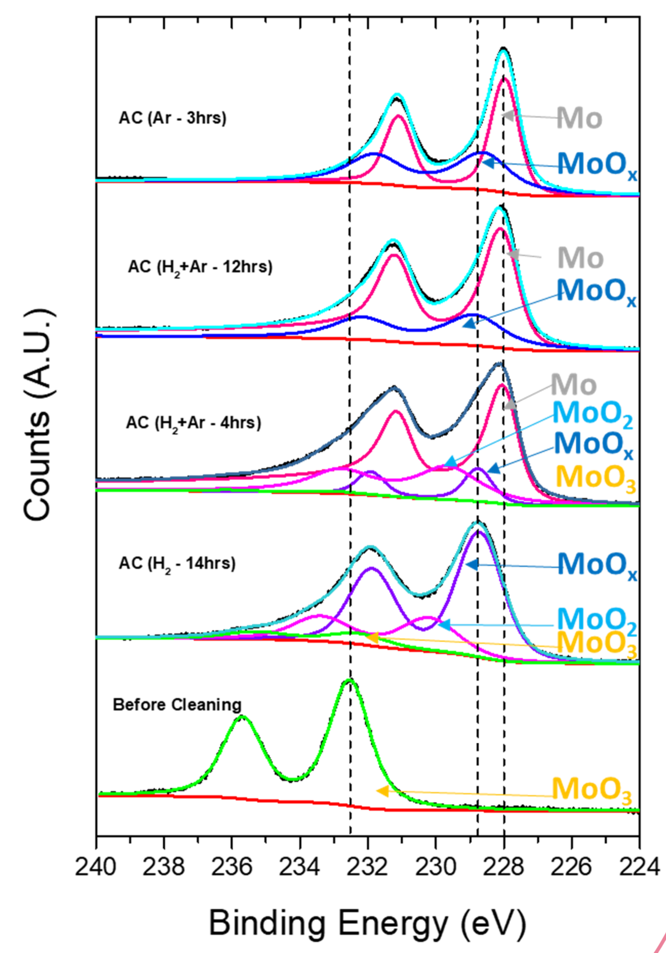
- Cleaning done in 3 steps (13.56 MHz, 0.5 or 1 Pa at 200V)

1. H_2 plasma cleaning
   - Chemical sputtering
   - Ineffective because of low sputtering yield



2. H_2+Ar (1:1) plasma cleaning
   - Ar added for higher sputtering yield
3. Ar plasma cleaning
   - Max. sputtering yield

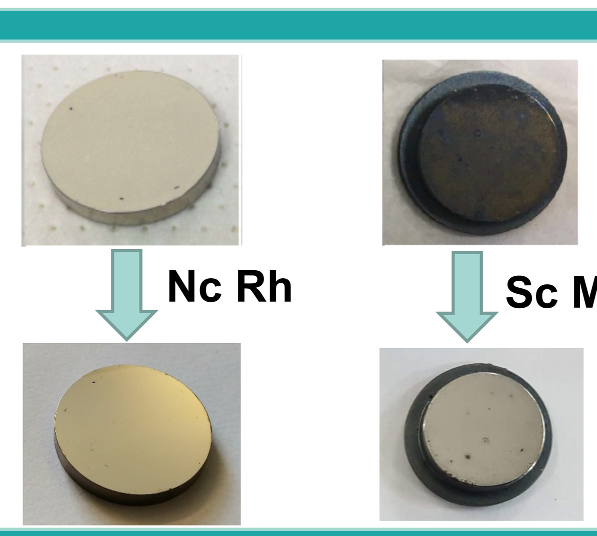




- **Total reflectivity recovered**
- **Diffuse reflectivity decreased**
- **Removal of Mo oxide**

Conclusions

- **Thin Rh oxide after steam ingress; thick Mo trioxide after steam ingress (120-170 nm).**
- **Cleaning with Ar plasma successfully recovered the pristine mirror properties. Hole density decreased with ongoing cleaning.**
- **Chemical sputtering with H_2 works, albeit needs Ar for higher sputtering yield and complete mirror recovery**.



FUSION FOR ENERGY

References

[1] **Pereira A.** *et al.*, **SG07 D04 Steam and humidity test report**, idm@F4E UID / VERSION **28KEAR / 1.0,** VERSION CREATED ON **16 May 2017,** EXTERNAL REFERENCE **P0000034819**.

Acknowledgements

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[1] INTA. Carretera de Ajalvir, Km 4, Torrejón de Ardoz. Madrid
[2] CIEMAT. Av, Complutense, 40. Madrid

University of Basel